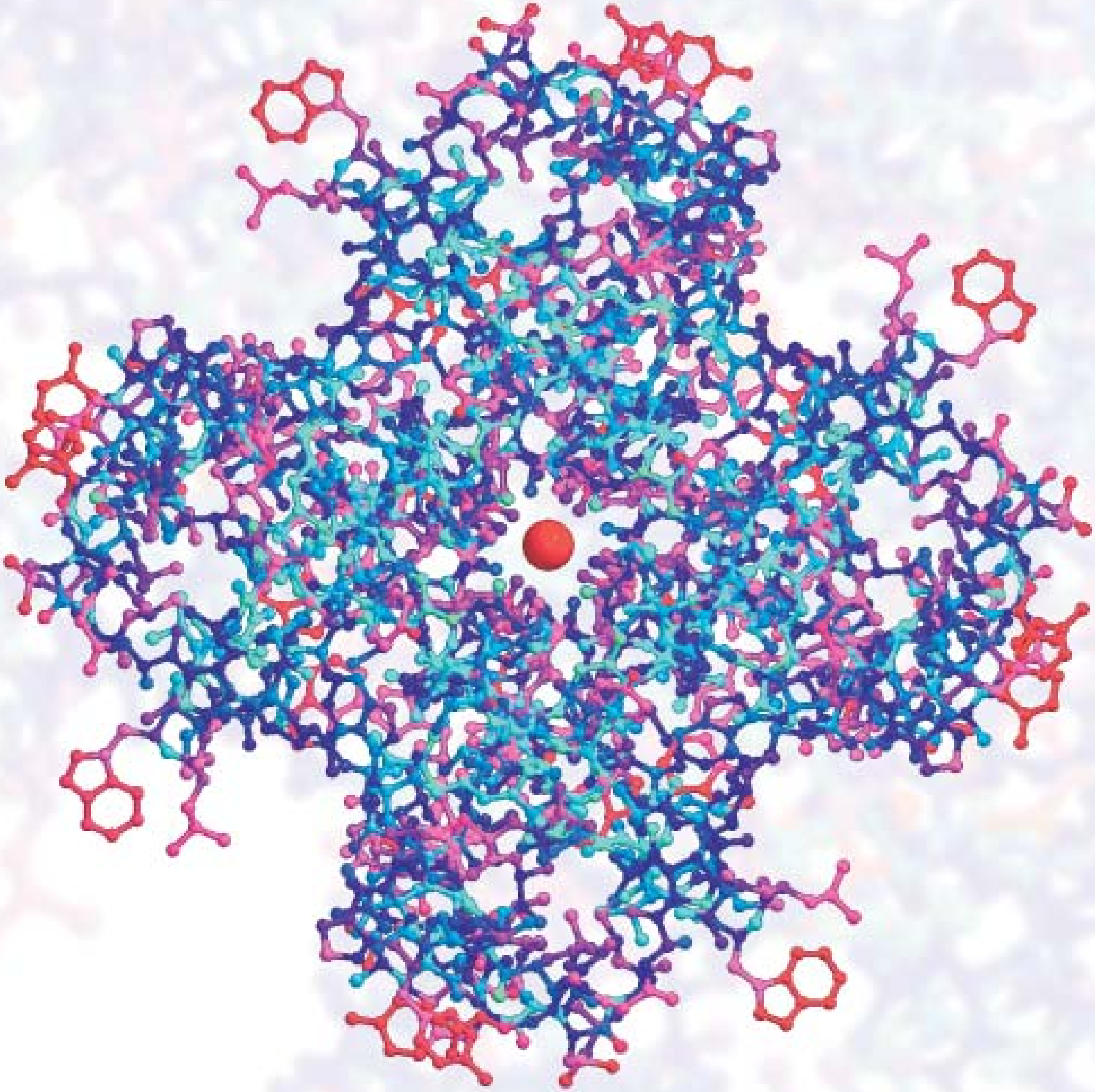
Science and Engineering Indicators 2004

Volume 1



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Science and Engineering Indicators
2004

Volume 1

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Cover Image

Model of the potassium channel in the bacterium *Streptomyces lividans.*

Roderick MacKinnon's discovery of the details of this structure and his explanation for how membranes pass electrical charge through cell walls led to his 2003 Nobel Prize in Chemistry. The potassium ion is shown in red at the center of the channel in the symmetrical structure. The surrounding four identical subunits of the protein are conserved in all known potassium ion channels. MacKinnon's work was supported by the National Institutes of Health at the Cornell High Energy Synchrotron Source (CHESS), a facility developed around an accelerator funded by the National Science Foundation originally built for studies of high-energy physics. (Cover image reprinted with permission from *Science* volume 280, number 5360, issue of 3 April 1998, copyright 1998 AAAS.)

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National Science Board

Letter of Transmittal

January 15, 2004

The Honorable George W. Bush
The President of the United States
The White House
Washington, DC 20500

Dear Mr. President:

It is my honor to transmit to you, and through you to the Congress, the sixteenth in the series of biennial Science Indicators reports, *Science and Engineering Indicators—2004*. The National Science Board submits this report in accordance with Sec. 4(j)1 of the National Science Foundation Act of 1950, as amended.

The Science Indicators series was designed to provide a broad base of quantitative information about U.S. science, engineering, and technology for use by public and private policymakers. Because of the spread of scientific and technological capabilities around the world, this report presents a significant amount of material about these international capabilities and analyzes the U.S. position in this broader context.

Science and Engineering Indicators—2004 contains quantitative analyses of key aspects of the scope, quality, and vitality of the Nation's science and engineering enterprise. The report presents information on science, mathematics, and engineering education at all levels; the scientific and engineering workforce; U.S. and international R&D performance and competitiveness in high technology; and public attitudes and understanding of science and engineering. In response to user demand, it contains a new chapter on state-level science and engineering indicators. An overview chapter presents the key themes emerging from these analyses.

This report demonstrates the strength the United States has derived from the open flow of ideas. Maintaining this openness and the relative advantage it has bestowed on the country remains crucial to the Nation's security and well-being. The proponents of openness, not those who stand ready to subvert science and technology for malevolent ends, are in the best position to exploit the fruits of science.

I hope that you, your Administration, and the Congress will find the new quantitative information and analysis in the report useful and timely for informing thinking and planning on national priorities, policies, and programs in science, engineering and technology.

Respectfully yours,

Warren M. Washington
Chairman

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The United States in a Changing World

Research and development in the United States has materially contributed to innovation and economic growth. The strong U.S. economic performance during the 1990s has given impetus to the trend toward a knowledge-based economy: that is, one in which research, its commercial exploitation, and other intellectual work play a growing role in driving economic growth.

That strong U. S. performance has become the benchmark against which governments around the world measure their countries' science and technology (S&T) activities and their progress toward a more knowledge-based economy. Seeking to emulate elements of the U.S. model of knowledge-driven economic growth, they are striving to expand knowledge-intensive sectors of their economies and are taking steps to develop the highly educated technical workforces they need to do so. The European Union (EU) has set a goal of becoming "the most competitive and dynamic knowledge-based economy in the world by 2010."[1]

U.S. investment and performance in R&D and S&T remain strong and progress toward a more knowledge-based economy continues. This progress takes place in an environment of increasing globalization of S&T-related activities as advances in communication and transportation, the cross-fertilization of ideas, increasingly open markets, and responses to significant cost differentials among competing countries spur innovation.

The United States has long benefited from the participation of large numbers of foreign-born scientists and engineers in the S&E workforce. Data from the 2000 U.S. Census show that in S&E occupations approximately 17 percent of bachelor's degree holders, 29 percent of master's degree holders, and 38 percent of doctorate holders are foreign born. These individuals contribute talent, scientific ingenuity, and technical sophistication to the U.S. S&T enterprise and help open up avenues for international scientific cooperation.

The outlook for U.S. S&E is affected by uncertainties in three major areas: the effects of policy adjustments arising from the September 11, 2001, attacks, the current weak worldwide economy, and developments affecting the U.S. S&E workforce.

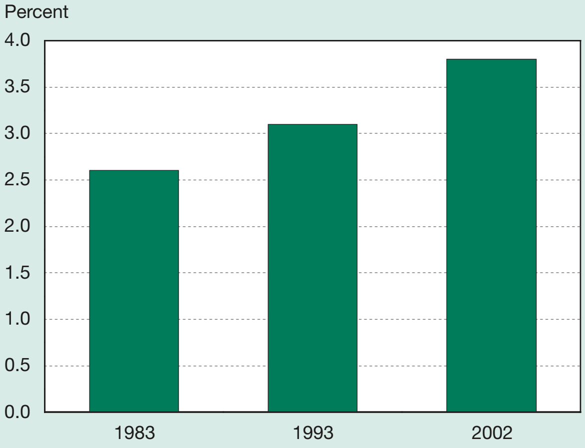
The first source of uncertainty is the recasting of the relationship between S&T and U.S. national security. The attacks of September 2001 have given increased urgency and a new focus to the changing strategic role of S&T in the post-Cold War era. The role of foreign students, scientists, and engineers in the U.S. S&E system; the appropriate balance between security and openness in scientific communication; the direction of certain Federal R&D initiatives; and the contributions that R&D can make in the domestic security arena are all issues of concern. The eventual resolution of these issues and the related effects on the U.S. S&T system remain unclear, particularly because only a few of the relevant data series available at this writing cover the 2002–03 period.

A second source of uncertainty is the duration, depth, and eventual effects of the current worldwide economic weakness. In particular, the effect this weakness will have on the structure and activities of high-technology firms around the world is unclear. As is the case with the aftermath of September 11, only fragmentary trend data are available that cover the 2002–03 period, and 1-year deviations from these trends are difficult to interpret with confidence.

A third source of uncertainty is the effect of the continuing globalization of labor markets on the U.S. knowledge-based economy. Employment in the U.S. S&E workforce has been growing significantly faster than overall employment for several decades (figure O-1), made possible in part by the U.S. ability to attract foreign-born S&E workers. The U.S. S&E workforce is entering a period of rising retirements, particularly among (but not limited to) doctorate holders. If present degree trends, retirement behavior, and international migration patterns persist, S&E workforce growth will slow considerably, potentially affecting the relative technological position of the U.S. economy.

The international S&E labor force is growing and becoming increasingly mobile. Governments are implementing policies designed to lure more of their citizens into S&E; keep their researchers at home or, in the case of the EU, in EU countries; and attract highly trained S&E personnel from abroad. Private firms are responding to competitive pressures and market opportunities by opening high-technology operations in foreign locations, developing strategic international alliances, and consummating cross-national spinoffs and mergers. A consequence of these trends is the further spread of technological know-how and the development of significant scientific and technical capacity in new locations across the globe.

Figure O-1
S&E occupation share of total civilian employment: 1983, 1993, and 2002



SOURCES: U.S. Bureau of the Census, Public Use Microdata Sample (PUMS), 1980 and 1990; and U.S. Bureau of the Census, Current Population Survey, 2000.

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[1] European Union, Lisbon, 2000.

As with the uncertain implications of security concerns and the weak economic environment, the dynamics of skilled labor migration in the context of changing government and industry policies also are hard to predict. Conclusions about their impact on the U.S. S&T position may require the accumulation of several years' worth of data to distinguish between temporary deviations from major trends and changes in the trends themselves.

The remainder of this overview sets out the main U.S. S&E trends in the context of national and international developments that affect the knowledge-based economy in the United States. It begins by looking at trends in R&D investment, discusses trends related to R&D outputs and performance, and considers S&E labor force indicators. The overview then examines two sectors of strategic importance to the development and use of knowledge: the academic sector, including Ph.D. employment, and the high-technology sector. It closes with a summary consideration of U.S. S&T competitiveness in an uncertain environment.

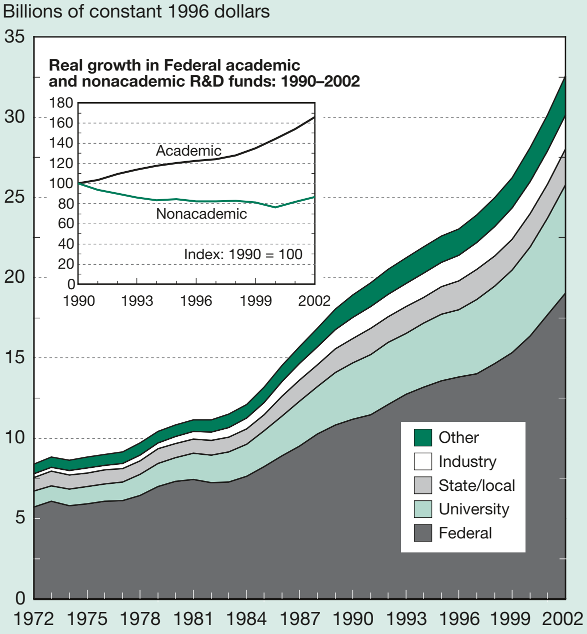
R&D Investment

U.S. strength in S&T reflects many decades of government support for the conduct of R&D, the development and maintenance of the necessary infrastructure, and the education and training of scientists and engineers. Federal R&D funds have been especially important to the academic sector, which is the source of much of the nation's basic research. Federal funds constituted close to 60 percent of academic R&D expenditures in the past decade. Since 1990, inflation-adjusted Federal dollars for academic R&D have grown continuously, increasing by about 66 percent through 2002. Real support to all other sectors declined during the decade, rebounding from its 2000 low but still contracting by about 14 percent over the period (figure O-2).

The strong U.S. R&D investment also reflects industry's commitment to R&D as an engine of competitive strength and profit growth. Company-funded R&D, which first surpassed federally funded R&D in 1980, reached a record $180 billion in 2000. Although it has slowed down sharply, it remained near this level in the face of 2 years of economic weakness. In 2002, U.S.-based firms spent an estimated $177 billion of their own funds on R&D, providing two-thirds of the national total of $276 billion (figure O-3).

This continued strength in industry spending for R&D—combined with an upswing in Federal Government support that mainly reflects increases in health-related R&D—has allowed the United States to maintain its longtime preeminence in the world's R&D activities. In 2001, the last year with internationally comparable data, U.S. R&D accounted for 44 percent of the combined R&D spending of the 30 member countries of the Organisation for Economic Cooperation and Development (OECD). The United States spent nearly three times as much on R&D as Japan, the nation with the second-highest total R&D expenditure. The U.S. total is half again as much as all EU countries combined

Figure O-2
Academic R&D expenditures, by source of funds: 1972–2002



SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), *National Patterns of R&D Resources;* annual series; and NSF/SRS, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 4-4.

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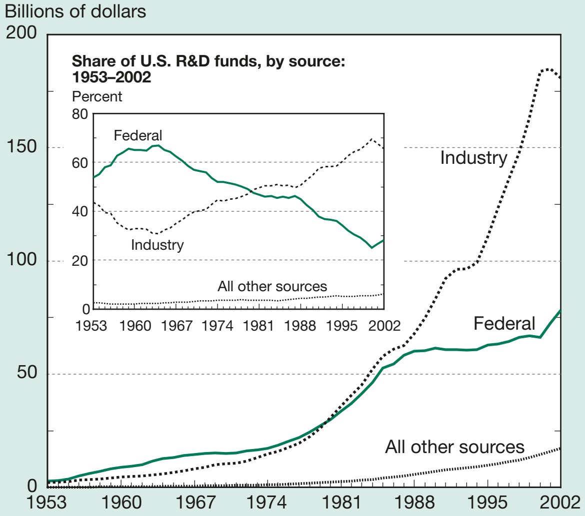
Figure O-3
U.S. R&D, by source of funds: 1953–2002



NOTE: Other sources include nonprofit, academic, and non-Federal government.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources;* annual series. See appendix table 4-5.

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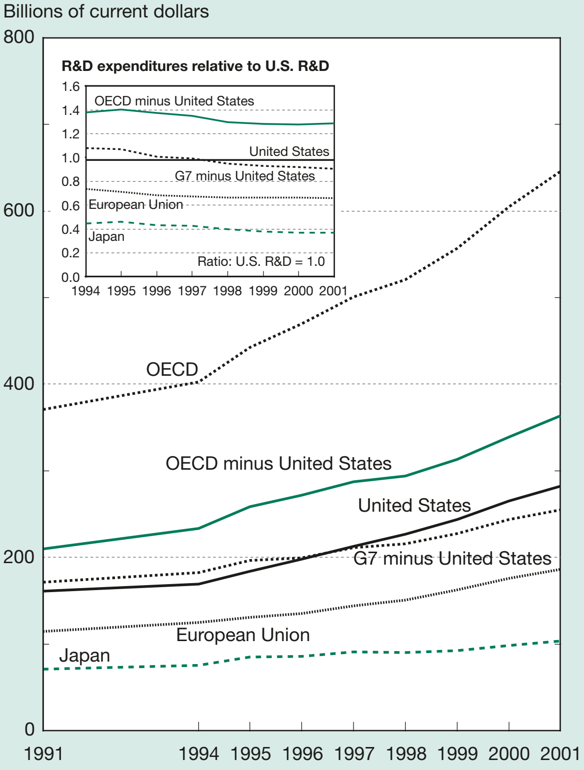
and more than the combined total of the other G-7 countries [Japan, the United Kingdom (U.K.), Canada, France, Germany, and Italy]. Relative to U.S. R&D expenditures, the EU and all of these countries except Canada lost ground over the period (figure O-4).

A significant development in industrial R&D performance in the United States (and to a lesser extent elsewhere) is the growth of R&D carried out in service-sector industries. Computer software firms and companies performing R&D on a contract basis primarily led this growth. U.S. service-sector R&D volume surged during the late 1980s and early 1990s and again after 1997.[2] In contrast to the United States, manufacturing industries—chiefly electronics, chemicals, motor vehicles, and electrical machinery—carry out almost all R&D in Japan. The EU shows a trend toward an increasing share of R&D by service-sector industries, but it remains well below 15 percent of the total (figure O-5).

Figure O-4
Gross domestic R&D expenditure, by selected country/region: Selected years, 1991–2001



G7 Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.
OECD Organisation for Economic Co-operation and Development

NOTES: OECD purchasing power parity units are based on U.S. dollars. All data for 1992 and 1993 are extrapolated.

SOURCE: OECD, *Main Science and Technology Indicators,* 2003 (1) (Paris, 2003).

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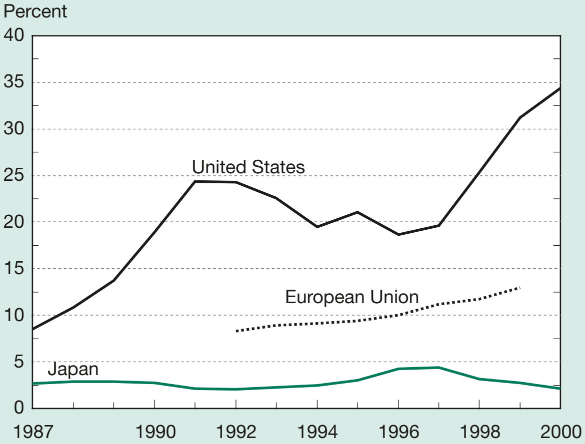
Figure O-5
Service-sector R&D share of industrial R&D in United States, European Union, and Japan: 1987–2000



SOURCE: Organisation for Economic Co-operation and Development, EAS, ANBERD database, July 2002. See appendix tables 6-7 to 6-9.

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The R&D environment has changed in response to developing global markets; closer links between R&D and the creation of new products, services, and markets; and the opportunities offered by advances in information and communication technologies. Industry has responded by outsourcing R&D both nationally and internationally, opening overseas operations, forming strategic technology alliances with U.S. and international partners, and engaging in both divestiture and acquisition of strategic technology units. U.S.-based companies have a prominent role in international alliances: the bulk of these strategic technology alliances have a U.S.-based firm as the ultimate parent company (figure O-6). The United States has also fostered the development of university-industry links and has stimulated the commercialization of "public" (mostly academic) research.

R&D Performance, Outputs, and Capabilities

The strength of the R&D performance of U.S.-based companies has attracted the attention of firms elsewhere. U.S. affiliates of foreign firms are increasing funds to conduct R&D in this country. In the late 1980s, U.S. companies provided $7.9 billion to their overseas affiliates for R&D, whereas foreign companies provided $6.7 billion to their U.S.-based affiliates. However, in the 1990s, these R&D investment trends reversed.[3] By 2000, R&D expenditures by foreign-owned firms in the United States had reached almost $26 billion, whereas overseas R&D spending of U.S. firms remained below $20 billion (figure O-7).

In S&E research output (as measured by publication in the world's key journals), the number of U.S. articles

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[2] The apparent acceleration in growth after 1997 may in part reflect changes in industry classification.

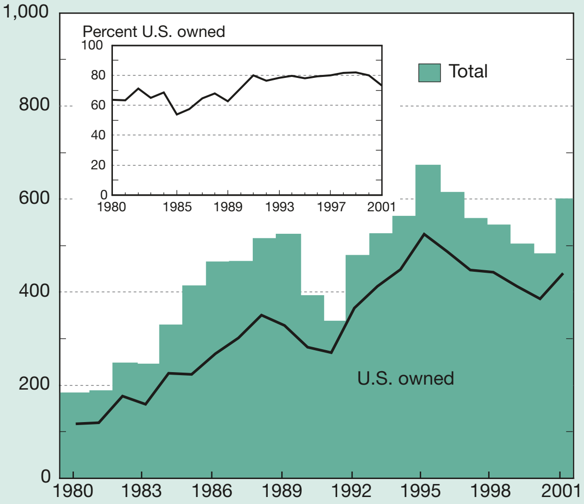
[3] Part of this development reflects mergers and acquisitions.

stopped increasing after the early 1990s. The U.S. share of world output has declined, indicative of the development of cutting-edge research capabilities elsewhere (figure O-8). Yet, U.S. researchers continue to make important contributions to the world's S&T knowledge as evidenced by the high volume of citations of their work by other researchers: articles by U.S. authors are cited abroad more frequently than might be expected based on their worldwide share of all articles. In many other countries' S&T publications, references to U.S. articles are more numerous than are references to the domestic literature (figure O-9).

International scientific collaboration continues to expand as more and more countries take part, and U.S.-based researchers are active participants. Domestic and international collaborations are expanding in response to the complexities of new scientific fields, the growing scale and scope of scientific initiatives, new capabilities provided by advances in information and communications technologies, professional ties established during study or work abroad, and explicit government policies and incentives.[4] In recent years, about 45 percent of the world's internationally coauthored articles had at least one U.S.-based researcher among their authors. Among coauthored articles published in the United States in 2001, nearly one-fourth had at least one foreign coauthor, up from 10 percent in the late 1980s (figure O-10).

Figure O-6
Total and U.S.-owned international technology alliances: 1980–2001

Number of new alliances



NOTE: Country assignment based on ultimate parent company of alliance members.

SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Co-operative Agreements and Technology Indicators database, special tabulations. See appendix table 4-42.

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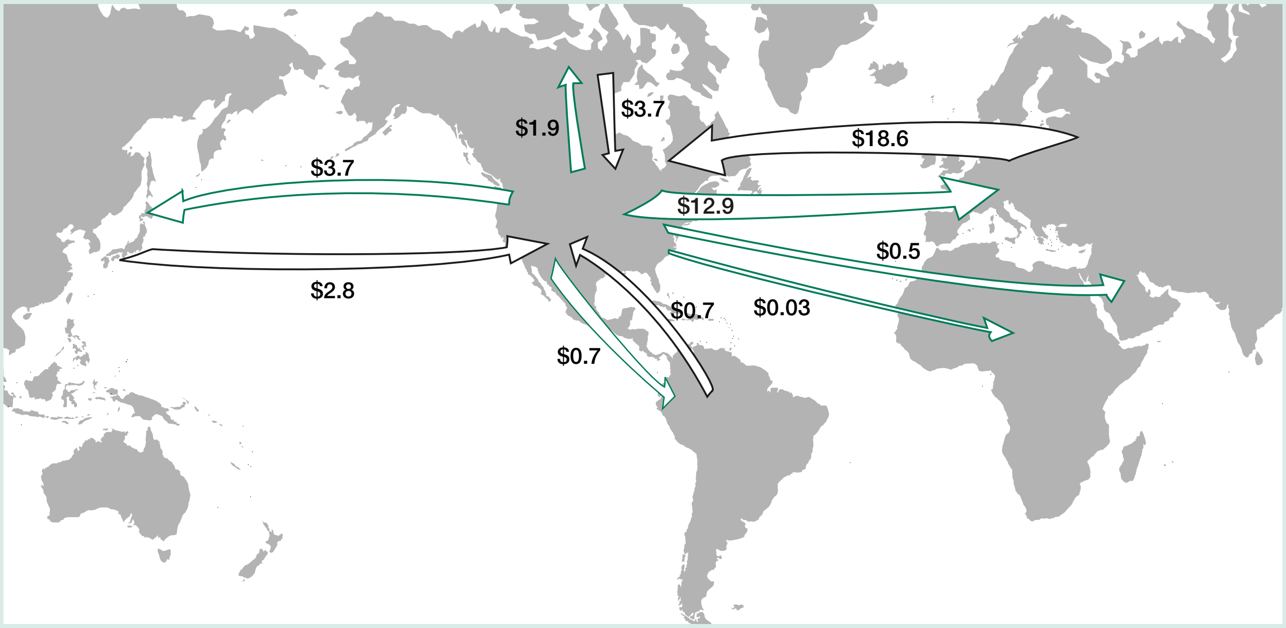
Figure O-7
Foreign-owned R&D in United States and U.S.-owned R&D overseas, by investing/host region: 2000

(Billions of current U.S. dollars)



SOURCES: U.S. Bureau of Economic Analysis, *Foreign Direct Investment in the United States,* annual series; and U.S. Bureau of Economic Analysis, *U.S. Direct Investment Abroad,* annual series. See appendix tables 4-49 and 4-51.

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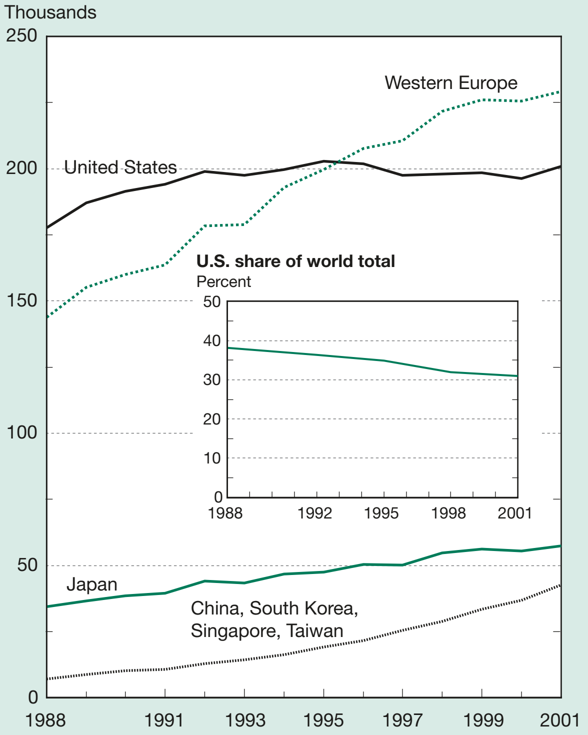
[4] The European Union's Sixth Framework Programme targets the creation of a European Research Area, in part through development of regional transnational centers of excellence and emphasis on transnational collaboration.

Figure O-8
S&E articles, by selected country/region and U.S. share of world total: 1988–2001



SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-35.

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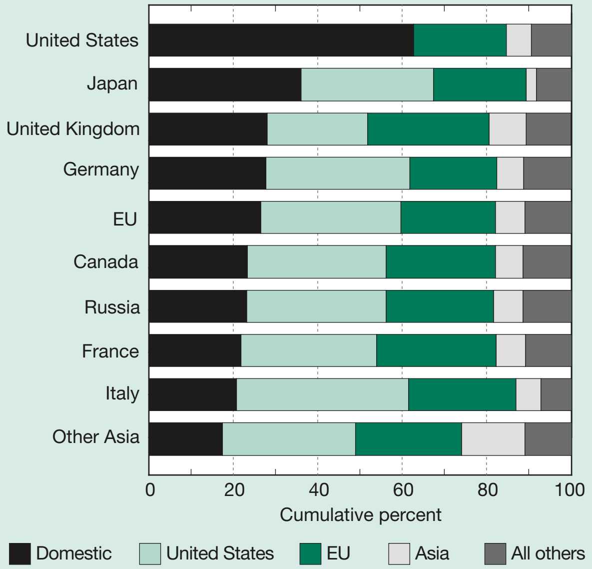
Figure O-9
International S&E articles cited, by country/region: 2001



EU European Union

NOTE: For EU members, EU articles cited refer to those of other EU countries. Other Asia excludes Japan. Asian articles cited by Japan and other Asian countries exclude domestically cited articles.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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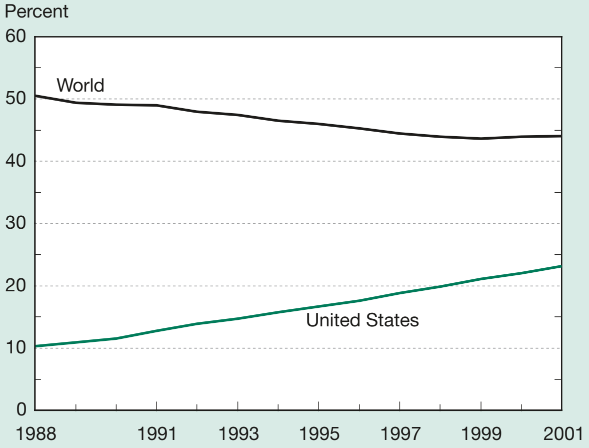
Figure O-10
World's internationally coauthored articles with one or more U.S. authors and U.S. articles with one or more foreign-based authors: 1988–2001



SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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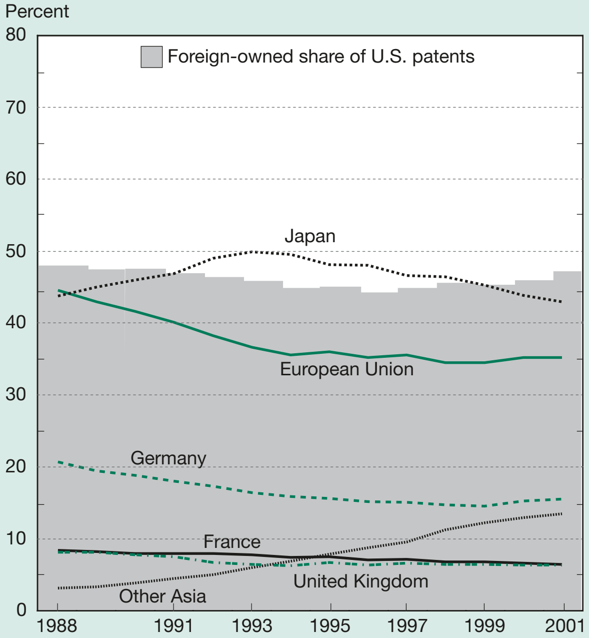
The volume of patents issued for inventions provides a broad measure of technological change, and the number of U.S. patents has surged, increasing from about 80,000 in 1988 to 166,000 in 2001. The large and dynamic U.S. market is attractive to foreign inventors, who have received between 44 and 48 percent of all U.S. patents since the late 1980s. The volume and nature of these foreign-owned patents provide insight into the relative technological competitiveness of other countries and regions in the U.S. market. Japan, with the largest share of foreign-owned U.S. patents, has seen that share decline since the early 1990s. The EU's share fell from the late 1980s to the early 1990s, then stabilized at about 35 percent. The share of selected Asian economies (China, South Korea, Singapore, Taiwan, and Malaysia) rose steeply, from less than 2 to 12 percent, which is indicative of their rapid technological progress (figure O-11).

U.S. inventors also are well represented in the patent portfolios of other nations. In most other countries, nonresident inventors account for a larger share of patents than they do in the United States. Among Western industrial countries, the foreign-owned share ranges from 60 percent in Germany to 90 percent in Canada; however, it is only 10 percent in Japan. In most countries, the United States received more

Figure O-11
Foreign-owned U.S. patents, by selected country/region: 1988–2001



SOURCE: U.S. Patent and Trademark Office, special tabulations. See appendix table 6-10.

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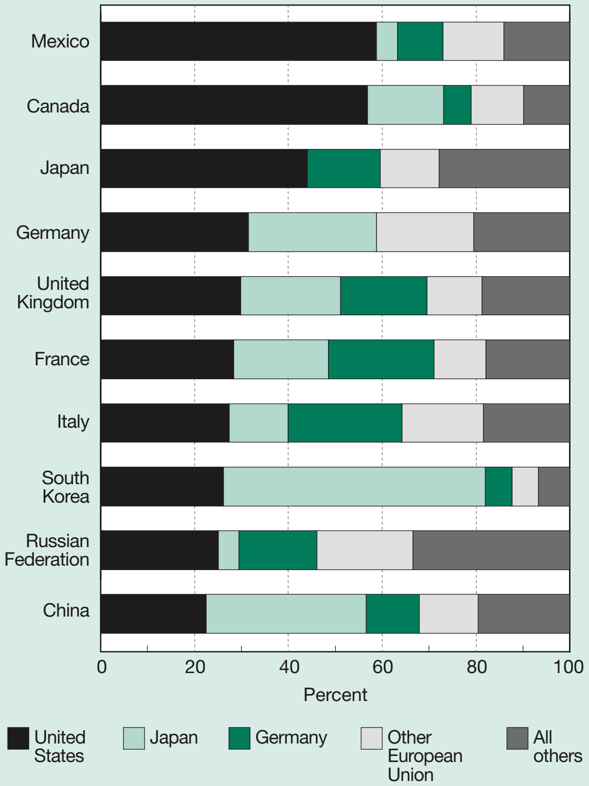
Figure O-12
Foreign-owned patents, by selected country: 2000



SOURCE: World International Property Organization, Industrial Property Statistics (Geneva, Switzerland, 2003). See appendix table 6-14.

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foreign patents than any other nation, followed by Japan and Germany. In China and South Korea, Japanese inventors led those from other countries (figure O-12).

Many countries are trying to stimulate university-industry links as a means of improving their innovation performance. Patents based on research results have become a valued output of academic R&D. In the United States, the number of patents awarded to academic institutions has risen to more than 3,000 annually (figure O-13). This is more than 5 percent of all U.S. inventor patents, compared with a share of about 1 percent 2 decades ago. During that period, the incidence of citations to S&E literature in all U.S. patents has risen to an average of about two citations per patent (figure O-13). The time lag between article publication and citation in patents has grown quite short, and the cited articles often appear in basic science journals, indicating an increasing tie between basic science and practical application.

S&E Workforce Trends

Many industrial countries have slow-growing or stagnating populations with rising average ages, and their young citizens are not inclined to enter S&E careers. Outflows of highly educated personnel to other countries, especially to the United States, are a growing focus of policy attention. Advanced developing nations are expanding their higher education systems and the high-technology sectors of their economies in an effort to develop internationally competitive centers of excellence. In the past, these countries have been a main source of internationally mobile scientific and technical talent, but recently some of them have developed programs designed to retain their highly trained personnel and to even attract people from abroad. Because their more developed counterparts also face this issue, these trends have set up the potential for growing competition in the recruitment of foreign talent and for continuing international mobility of firms to low-cost countries with well-trained workforces. In the United States, the issue of expanding the domestic S&E degree production is receiving increased attention.

Status of U.S. S&E Workforce

At the end of the past decade, about one-third of the 10.5 million people with bachelor's or higher degrees in S&E were employed in S&E occupations, holding job titles such as engineer; mathematician; and physical, life, computer, or social scientist.[5] Others worked in jobs not classified as

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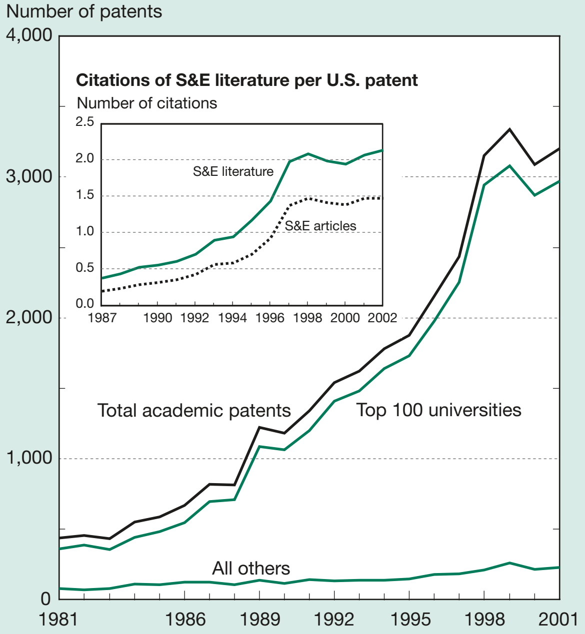
[5] The most recent available detailed data on the total S&E workforce are for 1999, but the broad patterns and trends discussed here are unlikely to be materially changed by more recent information, with one major exception. Data based on the 2000 Census show much higher rates of foreign-born scientists and engineers than earlier estimates derived from a sample based on the 1990 Census.

Figure O-13
Patents granted to U.S. universities and colleges: 1981–2001



NOTES: Citations to S&E articles are references to S&E articles in journals indexed and tracked by the Institute for Scientific Information's (ISI) Science Citation Index. Citations to S&E literature are references to S&E articles within and outside of ISI's coverage and non-article material such as reports, technical notes, conference proceedings, etc. Citation counts are based on a 12-year window with a 3-year lag. For example, citations for 2000 are references made in U.S. patents issued in 2000 to articles published in 1986-97. 2002 patent data are preliminary and subject to change. Average patent citations refer to all U.S.-issued patents.

SOURCES: U.S. Patent and Trademark Office, Institute for Scientific Information; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-54.

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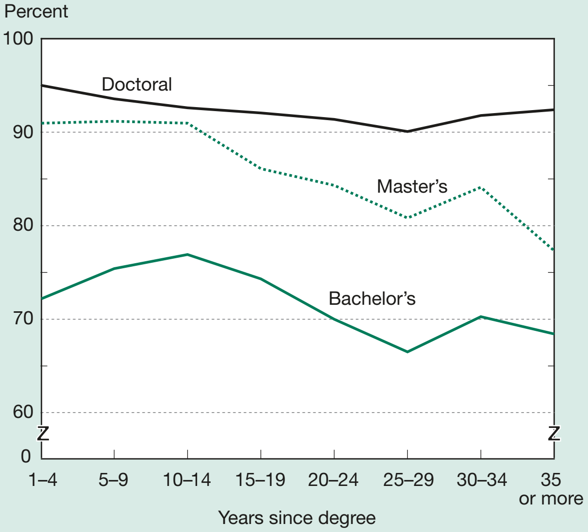
Figure O-14
S&E highest degree holders employed in jobs closely or somewhat related to highest degree, by years since degree: 1997



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999.

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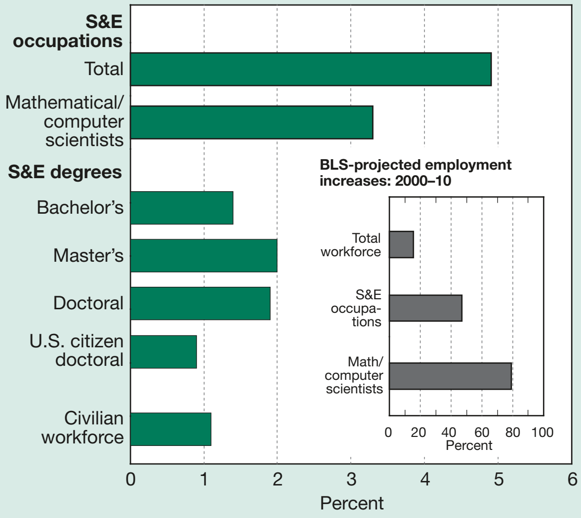
Figure O-15
Average annual growth rate of S&E occupations and degrees and U.S. civilian workforce: 1980–2000



BLS Bureau of Labor Statistics

SOURCES: U.S. Department of Labor, BLS, and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov.

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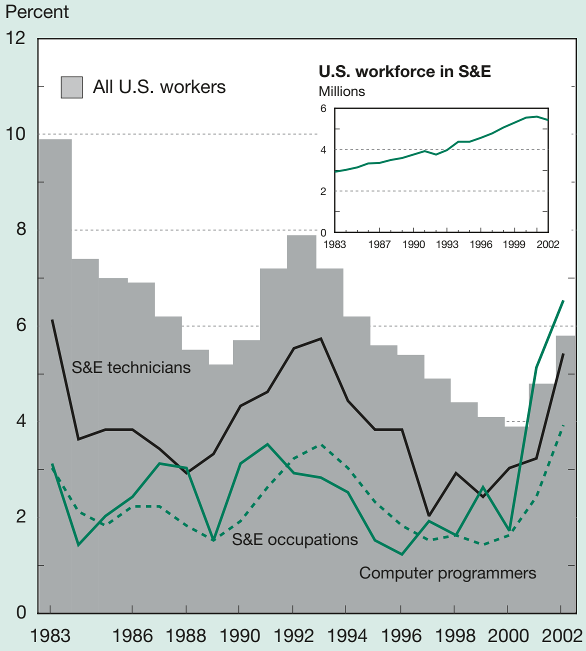
S&E, such as managerial, marketing and sales, planning, and quality control positions. In both types of jobs, their role is critical to the functioning of a knowledge-based economy. They produce new knowledge; transform it into innovative products, processes, and services; move these innovations into the marketplace; and develop entirely new markets. Even individuals who are not working in an S&E occupation in the later stages of their careers generally regard the nature of their S&E degree as related to their job (figure O-14).

The long-term growth of the S&E labor force has been considerably stronger than that of the civilian labor force as a whole, indicating a trend toward growing technical sophistication (figures O-1 and O-15). Since 1980, the number of S&E positions has risen at more than four times the rate of growth for all jobs, reflecting the transformation of the U.S. economy. Even if the creation of mathematician and computer scientist jobs is omitted, growth in the remaining S&E occupations still outpaced the growth of the civilian labor force as a whole. The growth rate of U.S. S&E degree production has exceeded the growth rate of the civilian labor force but lagged behind the growth rate of S&E occupations, which is indicative of the key role of foreign scientists and engineers in the U.S. S&E labor force. In fact, the number of S&E doctorates earned by U.S. native-born and naturalized citizens has grown more slowly than the growth rate of the overall civilian labor force.

The U.S. Bureau of Labor Statistics (BLS) projects differential growth that favors S&E occupations over the decade ranging from 2000 to 2010. Much of the projected difference is attributable to expected strong growth in mathematics/computer-related occupations. Even without the addition of these jobs, the growth rate of S&E jobs remains higher than the rate for the labor force as a whole, but not by an order of magnitude. Because the BLS projection has not been updated to reflect current difficulties in the information technology (IT) sector, those growth estimates are likely to change. An indication of the difficulties that the IT sector—and S&E employment in general—faces can be gleaned from employment and unemployment trends reflected in the BLS Current Population Survey.[6] BLS figures show that employment in S&E occupations rose strongly throughout the 1990s until 2001 (when it reached a record 5.6 million), and then declined to 5.4 million in 2002. Unemployment rates for S&E occupations, which traditionally have been lower than the national average for the civilian labor force as a whole, rose strongly in 2002. Breaking precedent, the unemployment rate for computer programmers exceeded the national average in 2002, and the rate for S&E technicians approached the average (figure O-16). Whether this signals a temporary or long-term slowdown in the IT sector is unclear.

Figure O-16
Unemployment rate, by selected occupations: 1983–2002



SOURCES: U.S. Department of Labor, Bureau of Labor Statistics, Current Population Survey; and National Bureau of Economic Research, Merged Outgoing Rotation Groups, special tabulations.

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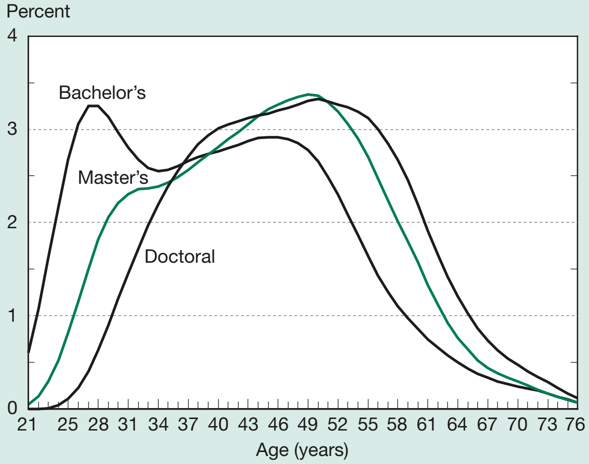
Retirements and Demographic Shifts

Unless current retirement rates change dramatically, the S&E workforce in the United States will experience rapid growth in total retirements over the next 2 decades. More than half of those with S&E degrees are age 40 or older, and the 40–44 age group is nearly four times as large as the 60–64 age group. Without changes in degree production, retirement behavior, or immigration, these figures imply that the U.S. S&E workforce will continue to grow, but at a slower rate than before, and that its average age will increase over the next 2 decades (figure O-17). These trends have placed attention on the needed replenishment of the U.S. S&E workforce, with a focus on domestic degree production.

Figure O-17
Age distribution of individuals with S&E degrees in U.S. workforce: 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), special tabulations.

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In recent decades, universities and colleges in the United States have educated a growing share of the college-age population. In 1980, there were 22 bachelor's degrees awarded per 100 24-year-olds (taken here as a proxy of the college-age population); by 2000 that number had risen to 34. During that period, the S&E share of all baccalaureate degrees fluctuated between 30 and 34 percent. The share of natural science and engineering (NS&E) degrees was more volatile, rising from 16 to 21 per 100 by the mid-1980s, and then declining to the current 17 per 100. Over the past decade, the number of bachelor's degrees in all fields rose by 18 percent, and the numbers for S&E and NS&E degrees increased by 21 and 24 percent, respectively. Increases in S&E degrees reflect strong growth in biological sciences, computer sciences, and psychology. However, since 1990, bachelor's degrees in engineering have declined by 8 percent and degrees in mathematics have dropped by about 20 percent (figure O-18).

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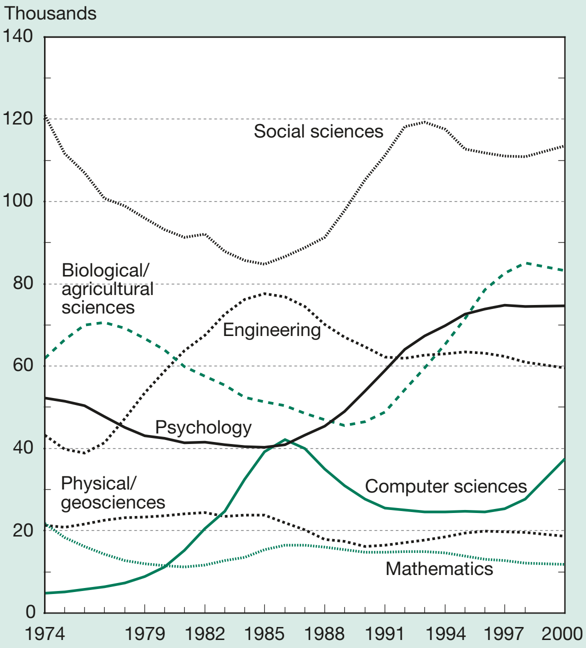
[6] This survey uses different definitions of S&E occupations than discussed previously.

Figure O-18
Bachelor's degrees earned in selected S&E fields: 1974–2000



SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov.

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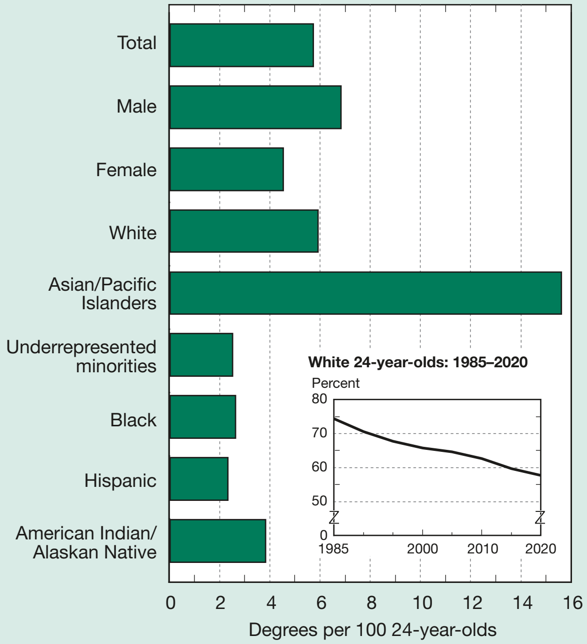
Demographic changes in the United States complicate the task of increasing the number of S&E degrees relative to the relevant age cohort. The proportion of non-Hispanic whites among 24-year-olds has been on a steady multidecade decline, falling from 74 percent in 1985 to a projected 58 percent by 2020. This shift largely reflects strong growth of population groups, especially Hispanics, that traditionally have been underrepresented in S&E. Students from these population groups earn associate's degrees more often than they earn bachelor's degrees. In recent years, their overall attainment rate for bachelor's degrees has been about half that of whites, and in NS&E, it has been less than half that of whites (figure O-19). Complicating the picture, S&E attainment rates by white non-Hispanic men have been on a long-term downturn that has been approximately counterbalanced by the rising participation of women.

Even as larger proportions of U.S. citizens avail themselves of higher education, the nation has lost the advantage it held for several decades as the country offering by far the most widespread access to higher education. Starting in the late 1970s and accelerating in the 1990s, other countries built up their postsecondary education systems, and a number of them now provide a first-level college degree to at least one-third of their college-age cohort. There is evidence that many countries are trying to increase production of degrees in NS&E. They appear to be succeeding in that goal well beyond what the United States has been able to achieve over the past 25 years (figure O-20).

Figure O-19
Ratio of NS&E bachelor's degrees to 24-year-old population: 2000



NS&E natural sciences and engineering

SOURCES: U.S. Bureau of the Census, Population Division; U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-4 and table 2-8.

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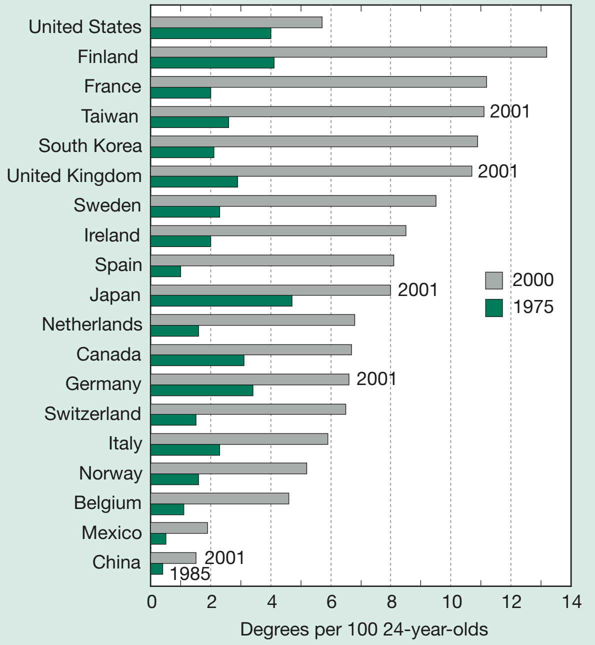
Degree Trends

Over the past 2 decades, three prominent trends in S&E degrees emerged. Among both U.S. citizens and noncitizens, women earned larger numbers of degrees, whereas the number of degrees earned by men rose more slowly or stagnated. Among U.S. citizens, underrepresented minorities increased their share of degrees, chiefly during the 1990s. More foreigners earned U.S. S&E degrees, especially advanced degrees, increasing both their total number and their share.

In 2000, women earned between 40 and 60 percent of bachelor's degrees in mathematics; physical, earth, ocean, and atmospheric sciences; and agricultural and biosciences. They also earned more than 75 percent of psychology degrees. Their share of engineering degrees increased from 2 percent in the mid-1970s to 20 percent, but their computer science share remained below one-third. The proportion of bachelor's degrees earned by white students declined from 87 percent in 1977 to 68 percent in 2000. During the 1990s, the number of degrees earned by white students decreased in all S&E fields except computer sciences, biological and agricultural sciences, and psychology.

The number of new S&E doctoral degrees rose strongly during the 1980s, and that trend continued through 1998; it then declined from its high of 28,800 to 27,100 in 2001.

Figure O-20
Ratio of first university NS&E degrees to 24-year-old population, by selected country/economy: 1975 and 2000 or most recent year



NS&E Natural sciences and engineering

SOURCES: U.S. Bureau of the Census, Population Division; national statistical agencies; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-33.

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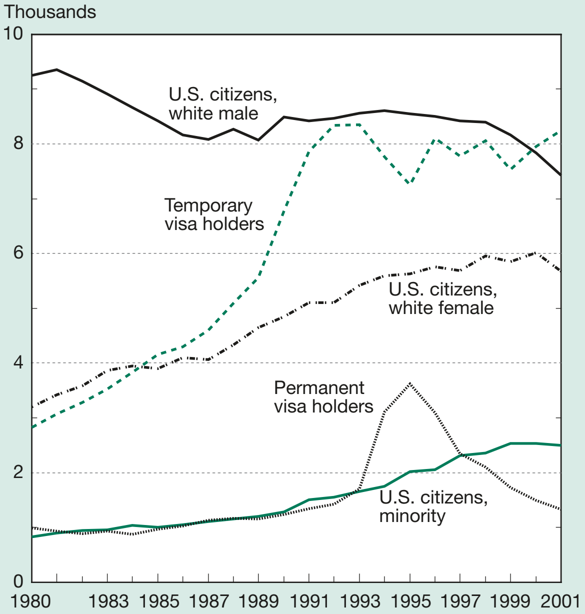
Figure O-21
S&E doctorates earned by U.S. citizens and noncitizens: 1980–2001



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations.

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Among U.S. citizens, the number of white non-Hispanic men earning Ph.D.s dropped from about 9,400 in the early 1980s to 7,500 by 2001, whereas degrees earned by white non-Hispanic women almost doubled and degrees earned by minority groups approximately tripled. Growth in S&E doctorates earned by temporary visa holders was strong during the 1980s, and that number has fluctuated at around 8,000 since the early 1990s. Their share of U.S. S&E doctorates rose from 17 to 33 percent over the period, with even higher percentages in mathematics, computer sciences, and engineering. The number of degrees earned by permanent visa holders spiked during the 1990s (reflecting the conversion to permanent visa status of Chinese students) but has since declined to previous levels (figure O-21). Overall S&E master's degree trends mirror those for doctorates, with the foreign-student component earning in excess of 25 percent of degrees earned, more than double the rate in the late 1970s.

The United States attracts many scientists and engineers who come here to work, and U.S. colleges and universities have trained many scientists and engineers from other countries. From 1985 to 2001, U.S. colleges and universities awarded about 150,000 S&E doctorates, 350,000 S&E master's degrees, and 270,000 S&E bachelor's degrees to temporary visa students. Many of these younger scientists and engineers stay on after completing their education, particularly if they receive doctoral degrees, and they continue to contribute to U.S. strength in R&D. Others go home or leave for other destinations, but often maintain ties with U.S. colleagues that contribute to collaborations across national boundaries (figure O-22).

U.S. Reliance on Foreign Talent

The United States has benefited for decades from a steady inflow of foreign scientists and engineers and continues to place greater reliance than other countries on foreign-born talent. This reliance has grown in both absolute numbers and relative share of foreign-born individuals in the workforce, especially during the 1990s. Census-based estimates of the proportion of foreign-born scientists and engineers working in the United States in S&E occupations[7] in 1990 and in 2000 show steep increases at every degree level (figure O-23). These increases reflect both the immigration patterns of the 1990s and the inflow of foreign specialists under various work visa categories.[8] The most recent figures, which are based on more complete data, exceed earlier minimum estimates developed without data on the entry of foreign-degreed nationals into U.S. S&E occupations from 1990 to 2000. These earlier (1999) estimates from the National Science Foundation's Scientists and Engineers Statistical Data System indicated 11 percent of bachelor's degree holders

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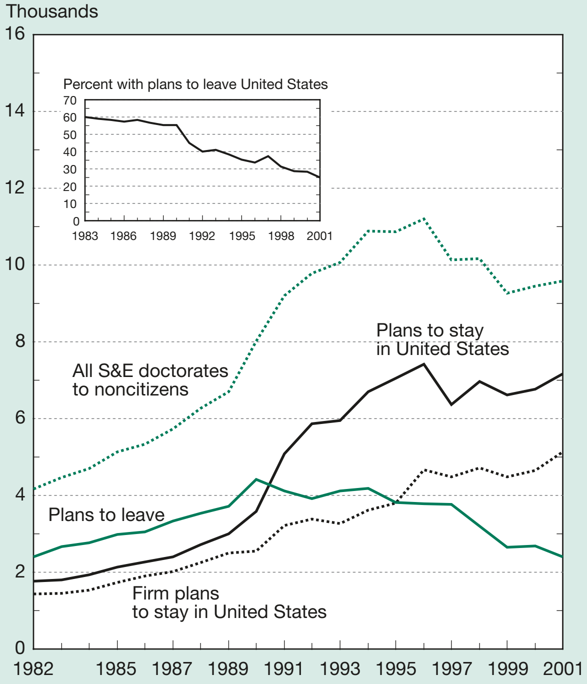
[7] People in occupations classified as S&E jobs. For technical reasons, postsecondary teachers are omitted.

[8] These figures exclude foreign-born, U.S.-educated scientists and engineers hired by U.S. firms into positions at their overseas affiliates.

Figure O-22
Foreign student plans after receipt of U.S. S&E doctorate: 1982–2001



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations.

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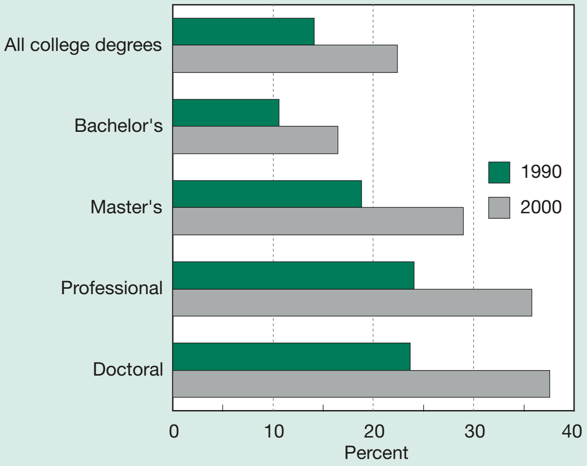
Figure O-23
Foreign-born scientists and engineers in U.S. S&E occupations, by degree level: 1990 and 2000



NOTE: Data exclude postsecondary teachers because field of instruction was not included in occupation coding for the 2000 Census.

SOURCE: U.S. Bureau of the Census, Public Use Microdata Sample (PUMS), 1990 and 2000 (5-percent sample).

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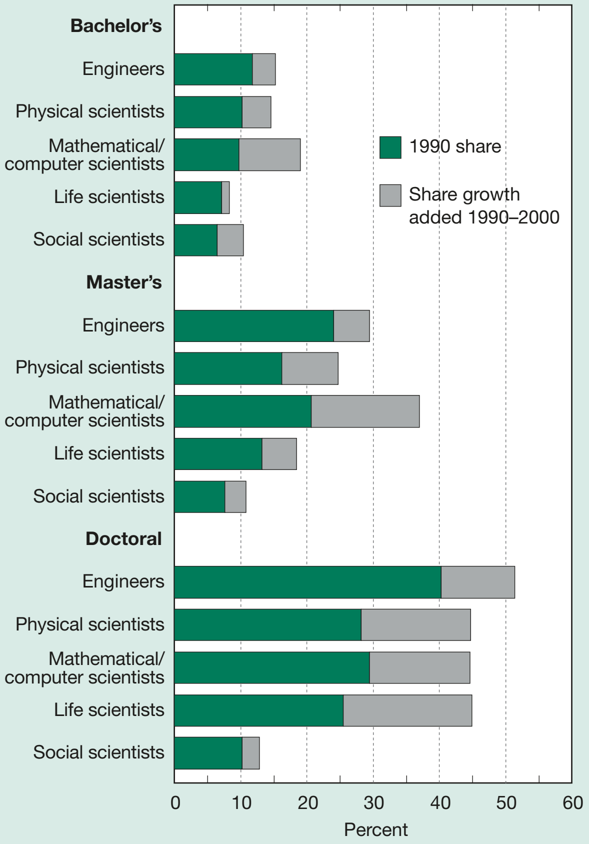
in S&E occupations were foreign born, compared with 17 percent according to the 2000 Census data; 19 percent of master's degree holders, compared with 29 percent; and 29 percent of doctorate holders, compared with 38 percent.

The share of foreign-born individuals varies according to their occupation and degree level. In 2000, approximately half of all doctorate holders among engineers; physical, life, and computer scientists; and mathematicians were foreign born. Among computer scientists and mathematicians, more than one-third of master's degree holders and approximately one-fifth of bachelor's degree holders were foreign born (figure O-24).

Graduate education in the United States has long been attractive to foreign students, and, over the years, their representation among all S&E graduate students has approached 30 percent. Foreign students with temporary visas represent half of all graduate enrollment in engineering, mathematics, and computer sciences, and one-third of enrollment in the physical, earth, ocean, and atmospheric sciences combined

Figure O-24
Foreign-born scientists and engineers in U.S. S&E occupations, by degree level and field: 1990 and 2000



NOTE: Data exclude postsecondary teachers because field of instruction was not included in occupation coding for the 2000 Census.

SOURCE: U.S. Bureau of the Census, Public Use Microdata Sample (PUMS), 1990 and 2000 (5-percent sample).

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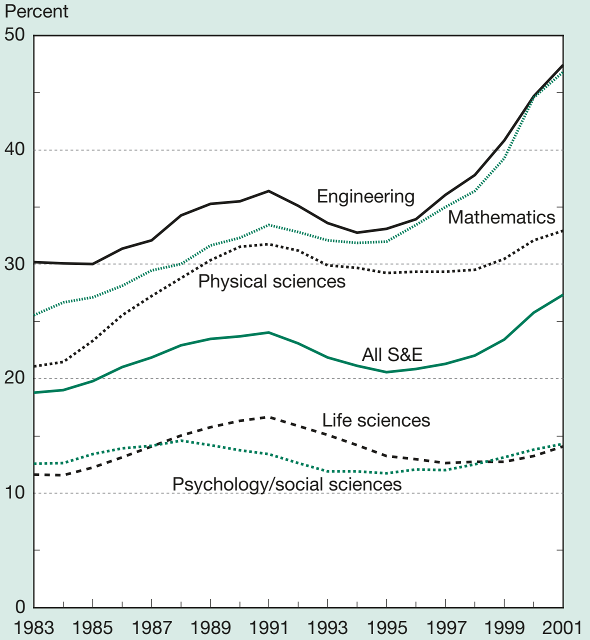
Figure O-25

S&E graduate students with temporary visas, by field: 1983–2001



NOTE: S&E includes health sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Postdoctorates and Graduate Students in Science and Engineering, special tabulations.

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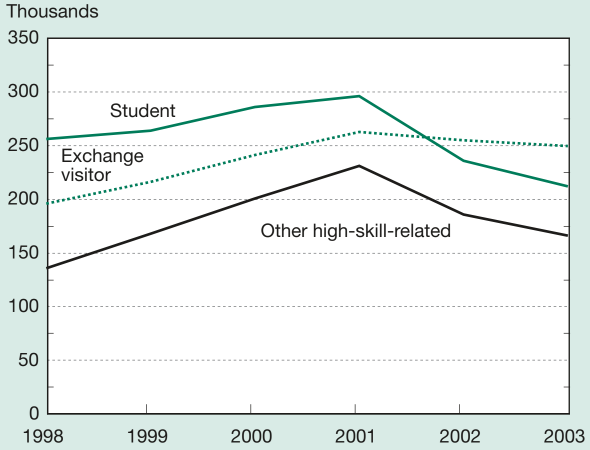
(figure O-25). The share of foreign students is much lower among undergraduates, as they earn approximately 4 percent of S&E bachelor's degrees; this rate has generally been steady. However, foreign students do earn approximately 8 percent of engineering and computer science bachelor's degrees.

The terrorist attacks of September 2001 have added a security dimension to ongoing discussions about the future of the U.S. S&E workforce, which focus on how and with whom to fill new positions and existing jobs vacated by retirement, especially in government or security-related areas. Available data indicate an initial reaction to the new security environment: the number of high-skill-related visas issued to students, exchange visitors, and others in 2002 was significantly lower than the number issued in 2001, and it continued to decline in 2003[9] (figure O-26). These data reflect both a drop in applications for all visa classes, except exchange visitors, and higher U.S. Department of State visa refusal rates (table O-1).

Figure O-26

Student, exchange visitor, and other high-skill-related temporary visas issued: FY 1998–2003



NOTES: Student visa is F-1, exchange visitor visa is J-1, and other visa categories include L-1, H-1B, H-3, O-1, O-2, and TN. See appendix table 3-24 for visa category definitions.

SOURCE: U.S. Department of State, Immigrant Visa Control and Reporting Division, 1998–2002.

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Table O-1

Visa applications and refusals by major high-skilled categories: FY 2001–2003

Visa action	2001	2002	2003
	Thousands		
Applications			
Student (F-1)	400.0	346.4	325.8
Exchange visitor (J-1)	279.5	278.6	295.6
Other high-skill related	248.4	203.6	200.2
	Percent		
Refusals			
Student (F-1)	27.6	33.3	35.2
Exchange visitor (J-1)	7.8	10.5	15.9
Other high-skill related	9.6	11.9	17.8

NOTES: Data for each fiscal year is through September 14 and excludes last 2 weeks of reporting. Other high-skill-related visas include L-1, H-1b, H-3, O-1, O-2, and TN visas.

SOURCE: U.S. Department of State, Immigrant Visa Control and Reporting Division, administrative data.

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Academic Employment

U.S. universities and colleges play a unique role in the U.S. R&D system. They conduct about half of the nation's basic research and, in so doing, train successive generations of scientists and engineers for R&D and other types of positions in all sectors of the economy. Like other sectors, academia is facing rising retirement rates among its largely doctorate-level scientists and engineers. More than 30 percent of its faculty are 55 years of age or older, and the total of individuals below age 45 has fallen to 36 percent (figure O-27). However, barring changes in degree production, retirement behavior, or foreign participation, there appear to be sufficient numbers of new doctorate holders to replace retiring incumbents and allow for some growth.

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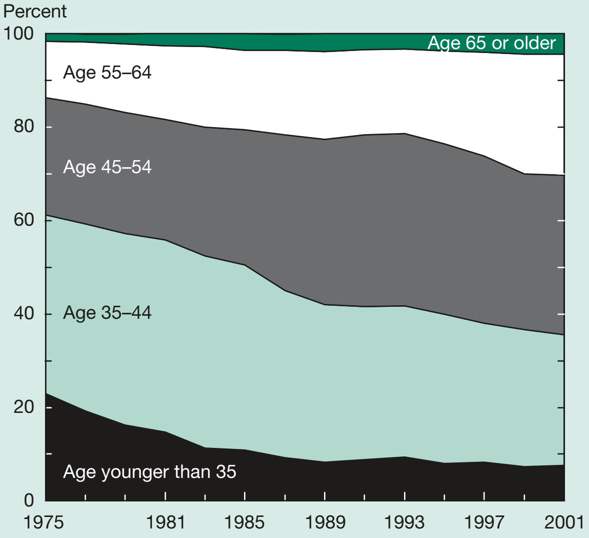
[9] Data are for October 1 through September 14 of each year.

Figure O-27
Age distribution of academic S&E doctorate holders employed in faculty positions: 1975–2001



NOTE: Faculty are employed full time as full, associate, and assistant professors and instructors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-21.

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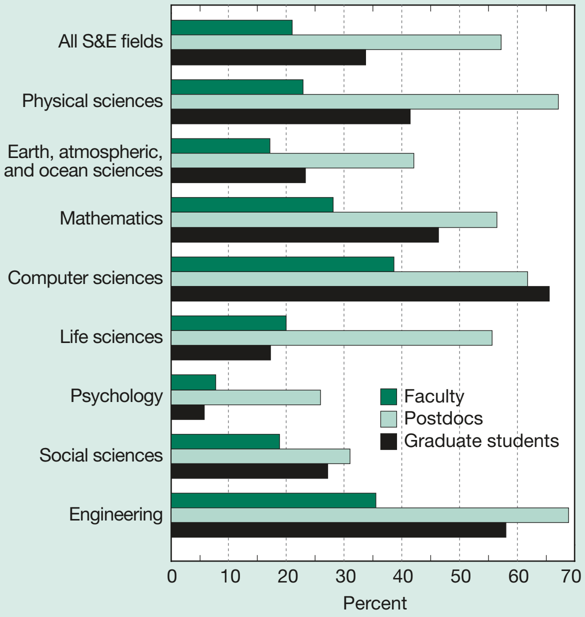
Employment of foreign-born S&E doctorate holders in academia shows a similar, but attenuated, pattern to that of industry. A minimum estimate is that about 25–30 percent of S&E doctorate holders employed in academia are foreign born; the rate is lower among faculty and higher among postdocs. Among faculty members, computer sciences, engineering, and mathematics have the highest shares of foreign-born individuals, ranging from 28 to 38 percent. Among postdocs, who play an important role in academic research, these figures are significantly higher, reaching almost 70 percent for engineering and 55–65 percent for most fields (figure O-28).

Postdoc positions have long played an important part in the early careers of physical and life scientists, and they have become more prominent in other fields as well. These positions are intended to provide further specialized training beyond the doctorate level, and the number of these positions has more than doubled since the mid-1970s, rising from about 22,000 to 47,000.[10] Almost all of them are in academia, but other sectors, chiefly industry, account for 10–14 percent. At present, most individuals in postdoc positions name reasons for accepting these positions that are consistent with the objective of obtaining further specialized training. For example, in 2001, only 12 percent stated that “other employment [was] not available,” a sharp drop from the 32 percent giving that response in 1999.

Figure O-28
Foreign-born share of S&E doctoral faculty, postdocs, and graduate students, by major degree field: 2001



NOTE: Because data include only U.S. doctorate holders, the foreign-born share is understated.

SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), Survey of Doctorate Recipients, special tabulations; and NSF/SRS, Survey of Postdoctorates and Graduate Students in Science and Engineering.

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An academic postdoc position is not necessarily a stepping stone to an academic faculty position. Of individuals in postdoc positions in April 1999, 37 percent were still in a postdoc position 2 years later, 12 percent had obtained tenure-track faculty positions, 20 percent held other types of positions at educational institutions, and 31 percent had found nonacademic employment.

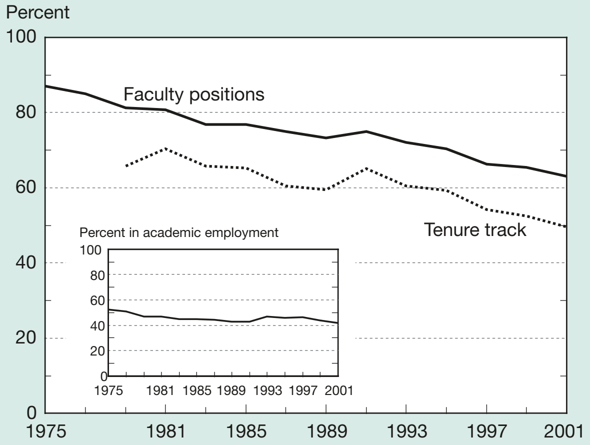
The perception that most S&E doctorate holders work in academia has been outdated for many years. Since the early 1980s, more than half of all S&E doctorate holders have worked in industry, government, nonprofit institutions, or elsewhere. That trend is most readily apparent for young Ph.D.s in full-time positions.[11] Over the past 3 decades, growing numbers of these S&E Ph.D.s have found employment outside academia as academia’s share has declined from 52 to 42 percent. Among individuals with academic appointments, growing numbers are hired for nonfaculty and postdoc positions. By 2001, only 63 percent held faculty positions, and only half were in tenure-track jobs (figure O-29).

---

[10] This number includes postdocs with non-U.S. doctorates.

[11] Young Ph.D.s are defined here as having earned their doctorate 4–7 years earlier.

Figure O-29
Faculty and tenure-track status of young academic S&E doctorate holders: 1975–2001



NOTE: Data are for individuals whose doctorates were earned 4–7 years earlier.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

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Health of U.S. High Technology

Indicators of the competitiveness of a nation's high-technology sectors provide a good measure of the performance of its S&T system. A nation's competitiveness may be judged by its ability to produce goods and services that find demand both in the global marketplace and at home while maintaining or improving its citizens' standard of living. For high-wage nations like the United States, high-technology industries and the S&E base on which they rest are the means of remaining competitive in today's global market.[12] These industries create new markets; produce a large share of innovations in goods, services, and processes; have high value-added production and above-average compensation levels; and compete in international markets. The results of their activities diffuse throughout the economy, leading to increased productivity and business expansion.

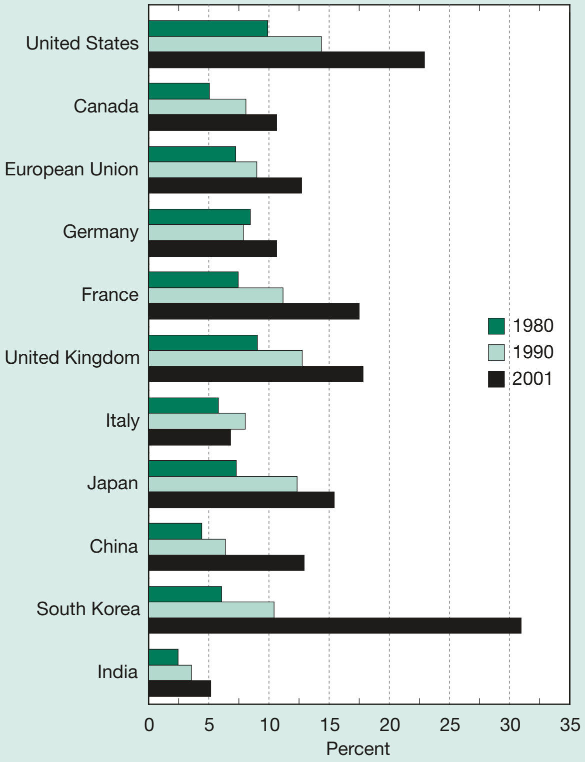
U.S. Performance in Knowledge-Intensive Industries

The U.S. economy continues to be the world's largest, ranking high on all measures of high-technology competitiveness. The global market for high-technology products has been growing faster than the market for other manufactured goods, increasing by a real growth rate that averages nearly 6.5 percent, compared with 2.4 percent for other manufactured goods. High-technology industries are driving economic growth around the world: their share of global manufacturing output rose from approximately 8 to 16 percent over the past 2 decades (figure O-30).

Many other nations have advanced their technological capacity and are challenging U.S. prominence in a variety of technology areas. The U.S. share of the global high-technology market, measured as the percentage of global industry shipments, declined from a high of 33 percent in the early 1980s to below 30 percent in 1991; in recent years, it has held steady in the 32–33 percent range. The EU market share has gradually declined over the past 2 decades, largely reflecting losses by Germany, the United Kingdom, and Italy; only France gained share over the period. Declines by the EU and Japan contrast with the strong rise of China and South Korea (figure O-31).

The United States continues to hold the largest world market shares in four of the five high-technology industry sectors, with U.S. companies generally losing ground to competitors during the 1980s and gaining it back during the 1990s. The only exception is in pharmaceuticals, where the EU has held the lead position for the past 2 decades at 30–34 percent (figure O-32). In aerospace, the United States has accounted for about half of all shipments since the late 1990s but has lost some ground to the EU (30 percent in 2001). China showed strong growth in that sector, increasing

Figure O-30
High-technology industry share of total manufacturing output, by selected country/region: 1980, 1990, and 2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003.

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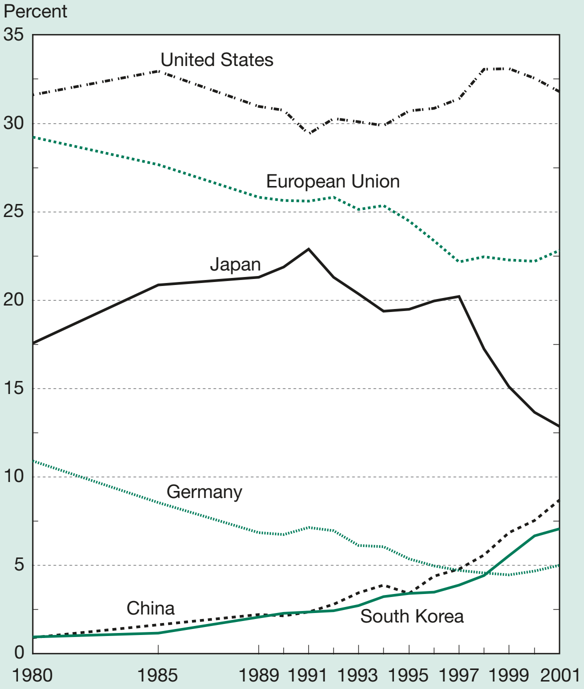
[12] Following the OECD definition, high-technology industries are defined by their R&D intensity and include aerospace, pharmaceuticals, computers and office machinery, communications equipment, and scientific instruments.

Figure O-31
Global high-technology market share, by selected country/region: 1980–2001



NOTE: Data for 1981–84 and 1986–88 are extrapolated.

SOURCE: Global Insight, Inc., World Industry Service database, 2003.

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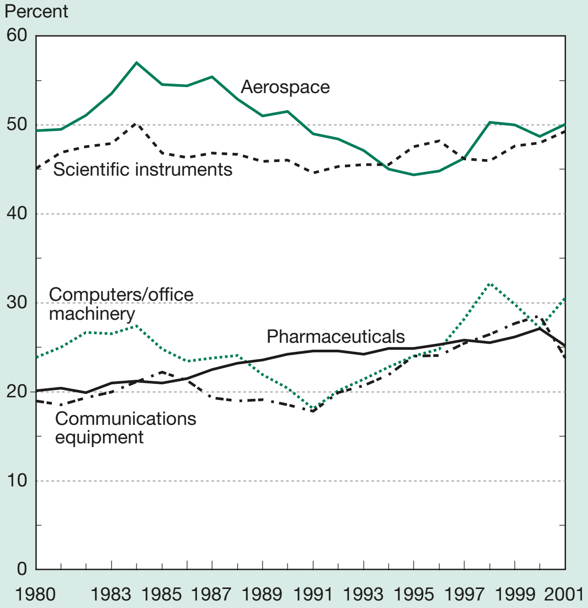
Figure O-32
U.S. global high-technology market share, by industry: 1980–2001



NOTE: Share of total world shipments by industry.

SOURCE: Global Insight, Inc., World Industry Service database, 2003.

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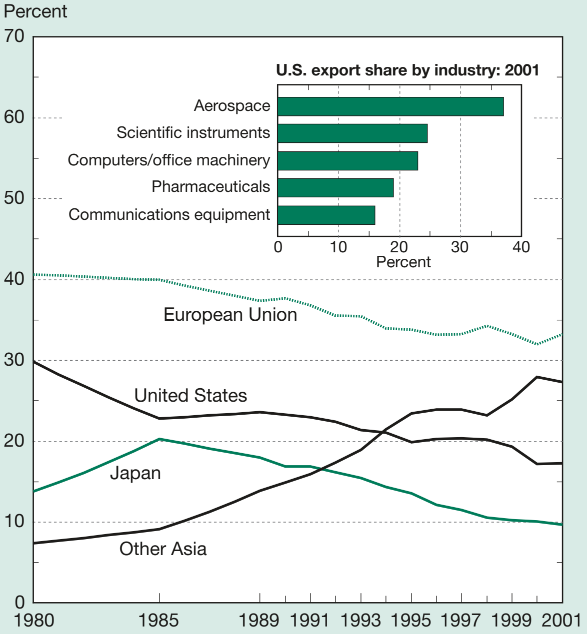
from less than 1 percent to nearly 7 percent in 2001, whereas Brazil's share dropped sharply, falling to 3 percent from 15 percent 2 decades earlier. China registered strong gains in the communications equipment and computers and office machinery industries; South Korea also showed consistent growth in the latter area.

Exports reflect the success of an economy's products in international markets. U.S. high-technology exports declined from 23 to 19 percent of the world's total during the 1990s, but the United States continued to produce a positive trade balance in high-technology goods. (The United States ranked second behind the EU, which also lost export market share, as did Japan.) In contrast, the remainder of the Asian region has rapidly gained market share over the past 2 decades; the combined high-technology exports of China, South Korea, Malaysia, Singapore, and Taiwan rose from 8 percent in the early 1980s to nearly 28 percent in 1999. The flattening of these countries' market share in 2000 and 2001 reflects downturns in exports of communications equipment and computers and office machinery (figure O-33).

The decades-long growth in the importance of the U.S. service-sector industries to the nation's economy has largely been driven by communications, financial, business (including computer software development), education, and health services. These knowledge-intensive industries incorporate science, engineering, and technology in either their services or the delivery of their services. The first three industries

Figure O-33
Global high-technology export share, by selected country/region: 1980–2001



NOTES: Other Asia includes China, South Korea, Malaysia, Singapore, and Taiwan. Data for 1981–84 and 1986–88 are extrapolated.

SOURCE: Global Insight, Inc., World Industry Service database, 2003.

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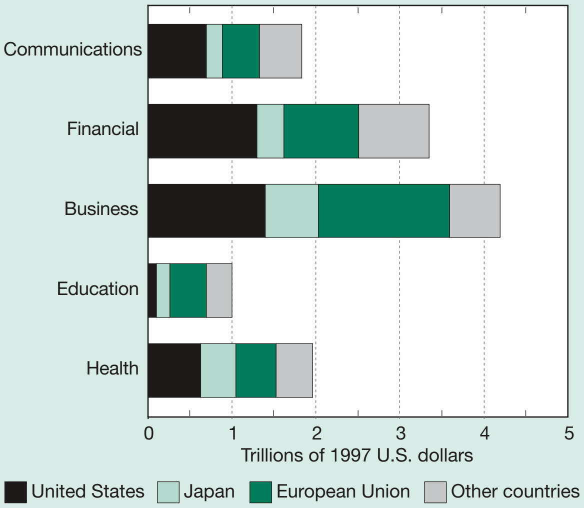
have global markets; health services and education tend to be more local, often largely provided by governments, and reflect population size differences, thus making international share comparisons less meaningful. Combined global sales of all five service industries rose in inflation-adjusted terms from $5.4 trillion in 1980 to $8 trillion in 1990, and then to $12.3 trillion in 2001 (figure O-34).

The United States has been the leading provider of high-technology services, accounting for about one-third of the world total throughout the past 2 decades. It held the largest market share in financial services (40 percent), followed by the EU and Japan (26 and 10 percent, respectively). It also led in communications services (38 percent compared with the EU's 24 and Japan's 11 percent). The EU held the largest market share in business services at 37 percent, followed by the United States and Japan (34 and 15 percent, respectively).

Firms increasingly license or franchise proprietary technologies, trademarks, and entertainment products across national boundaries, generating royalties and licensing fees from these transactions. The United States has traditionally shown a large and growing trade surplus in these intellectual-property transactions, which include cross-border payments between affiliated and unaffiliated companies. However, since the mid-1990s, this surplus has been declining. Examining only payments for use of intellectual property between unaffiliated companies more accurately reflects the value of technical know-how being traded. Here again the United States is a net exporter, with overall receipts about three times as large as U.S. payments to companies abroad (figure O-35).

Around the world, the availability of venture capital financing in the United States is viewed as key to the nation's rate of new firm creation and overall economic vitality. U.S. venture capital disbursements rose gradually from the early 1980s until 1994, reaching a level of just over $4 billion. These disbursements then rose more rapidly, reaching $22 billion by 1998 and soaring beyond $100 billion in 2000 at the height of the dot.com boom. Disbursals in 2001–02 dropped back to 1998–99 levels, which are still high by historical standards (figure O-36). During the 1990s, most funds

Figure O-34
Global revenue generated by knowledge-intensive service industries, by selected country/region: 2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003.

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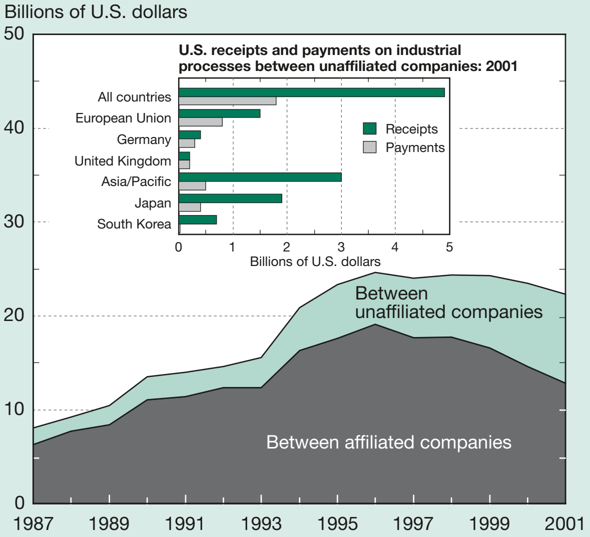
Figure O-35
U.S. trade balance in royalties and fees: 1987–2001



SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, Survey of Current Business.

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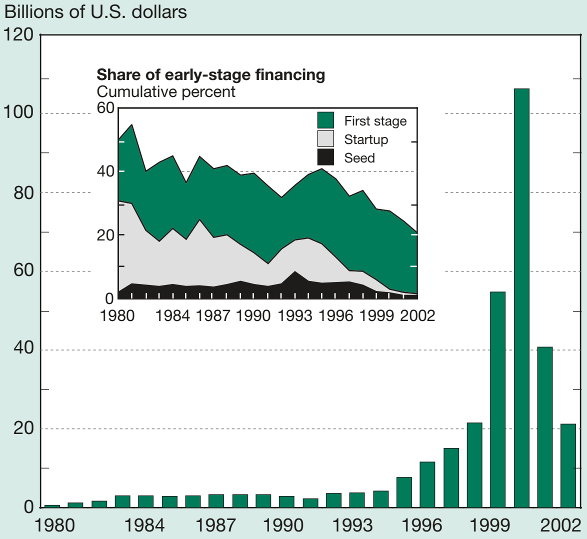
Figure O-36
U.S. venture capital disbursements: 1980–2002



NOTE: Seed funds are for proof of concept, startup funds for product development/early marketing, and first-stage funds for capital replenishment.

SOURCE: Thomson Venture Economics, special tabulations.

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were directed to companies engaged in computer hardware and software production and related services and to medical and health care firms. Internet-specific companies became the leading recipients in 1999–2000, receiving more than 40 percent of the total, and they continued to receive more than 20 percent of the total in 2001–02. In the United States, the availability of early-stage financing remains a concern because of a shrinking share of total disbursed funds. Funds for proof-of-concept work and early product development and initial marketing have fallen to a historic low of 1.5 percent.[13]

Conclusion

Many decades of investment in R&D have helped to lay the basis for an S&E system that generates about one-third of the world's research articles, a multitude of technological innovations, and numerous high-technology industries that exploit innovations to their profit and to the nation's economic benefit. The United States has maintained its scientific and technological edge in the world even as new centers of scientific and technical know-how and innovation have emerged. It attracts many of the world's best scientists and engineers, remains the world's leading producer of high-technology products, and benefits from the rapid growth of knowledge-intensive service industries. Its policies and practices are studied around the world as models that might be applied by other countries in their efforts to boost their competitive standing in a world that is moving toward more knowledge-intensive industries.

Although the United States remains the world's S&T leader, a collection of trends in indicators of U.S. S&T competitiveness paints a more differentiated picture. In R&D performance, the United States is slowly widening the gap with other leading nations and regions such as the EU, non-U.S. G-7 countries, and non-U.S. OECD nations. However, some non-OECD economies, including China, the Russian Federation, and Taiwan, are slowly raising their spending relative to that of OECD members. In S&E research output, as measured by publications in the world's key journals, the U.S. share continues to decline, indicative of the development of cutting-edge research capabilities elsewhere. The overall U.S. world market share in high-technology products is steady, but the nation's aerospace industry is losing market share. Although the U.S. balance in intellectual products trade remains positive, it is showing signs of a gradual decline.

A range of indicators traces a trend that shows growing competitive strength in the Asian region outside of Japan, chiefly in China, South Korea, Malaysia, Singapore, and Taiwan. Scientists based in those countries produce a growing share of the S&T articles appearing in the world's leading journals, and development of regional scientific collaboration (centered on China) is apparent. These Asian economies have an expanding world market share of high-technology production. In exports of high-technology products, they are gaining market share on all major industrial nations including the United States. They are increasing their production of S&E degrees with a special focus on NS&E, thus providing a growing stream of new technical talent for their economies. They have in place, or are instituting, policies and incentives to retain their highly trained personnel, attract expatriates, or otherwise benefit from their nationals working abroad, chiefly in the United States.

As nations have turned to the task of developing a broader base of knowledge-intensive industries, they face the necessity of rethinking their workforce needs. Many are further expanding their education systems, placing emphasis on S&T training. Japan and the mature industrial nations of Europe, which have aging and declining or stagnating populations, are seeking an inflow of scientists and engineers from abroad as well as the return of their own researchers from other countries. All of these nations face declining interest in S&E among their young people, and all emphasize the importance of attracting more women to S&E careers. Increasingly, these nations seek to attract foreign students: there is growing interest in what makes the United States attractive to people from around the world as a place to study and work.

The United States faces somewhat different issues connected with the development of the S&T workforce. Like the other industrialized nations, the United States faces a period of growing retirements among its S&E workforce. Unlike them, it has a growing population whose average age is projected to decline rather than increase. Its college-age population will increasingly be made up of minority group members, such as Hispanics, blacks, and American Indian/Alaskan Natives, whose current participation rates in S&E are half or less those of white non-Hispanic students. As lower proportions of white non-Hispanic men obtain S&E degrees, the importance of women and minorities pursuing degrees in these fields rises.

Over the past 2 decades, the U.S. S&E workforce has grown at more than four times the rate of total employment, in part because of the U.S. ability to integrate large numbers of foreign-born scientists and engineers into its workforce. Nevertheless, barring changes in current retirement, degree production, and immigration trends, the growth of the S&E workforce will slow down, leading to a rising average age.

Information about some key indicators is missing. This scenario does not include the potential effects on foreign scientists' longer term willingness to work or study in the United States caused by the nation's reaction to the attacks of September 2001. It does not reflect restrictions the U.S. government might place on foreign scientists' access to the United States. Most important, it does not include indicators on U.S.- and foreign-based firms' inclination to locate operations overseas in pursuit of new markets, well-trained talent, and lower costs.

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[13] Early-stage financing includes seed funds for proof-of-concept, startup funds for product development and initial marketing, and first-stage funds for capital replenishment to initiate commercial manufacturing and sales.

Chapter 1

Elementary and Secondary Education

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Highlights

Student Performance in Mathematics and Science

- ♦ **Student performance in mathematics and science, as measured by the National Assessment of Educational Progress (NAEP), has improved somewhat over the past 3 decades, but not consistently.** Improvements have occurred across all racial/ethnic subgroups.
- ♦ **Despite the improved performance overall, achievement gaps between various racial/ethnic subgroups persist and have shown no signs of narrowing since 1990.** For example, in NAEP's 2000 mathematics assessment of grade 12 students, 74 percent of white students and 80 percent of Asian/Pacific Islander students scored at or above a level deemed basic by a national panel of experts. In contrast, 31 percent of blacks, 44 percent of Hispanics, and 57 percent of American Indians/Alaskan Natives attained this level.
- ♦ **Achievement gaps between males and females have largely disappeared, especially in mathematics.** For example, in tests administered by the Program for International Student Assessment (PISA) in 2000, 15-year-old male and female students scored equally well in both mathematics and science literacy.
- ♦ **U.S. students are performing at or below the levels attained by students in other countries in the developed world.** U.S. students' performance on PISA was about average among Organisation for Economic Co-operation and Development (OECD) countries. Seven countries (Australia, Canada, Finland, Japan, New Zealand, South Korea, and the United Kingdom) had higher scores in both mathematics and science. Six countries recorded lower scores in both subjects: Brazil, Greece, Latvia, Luxembourg, Mexico, and Portugal.
- ♦ **In international comparisons, U.S. student performance becomes increasingly weaker at higher grade levels.** On the Third International Mathematics and Science Study (TIMSS), U.S. 9-year-olds scored above the international average; 13-year-olds, near the average; and 17-year-olds, below it. On advanced mathematics and science assessments, U.S. students who had taken advanced coursework in these subjects performed poorly compared with their counterparts in other countries.

Mathematics and Science Coursework and Student Achievement

- ♦ **Since the publication of *A Nation At Risk* 20 years ago, many states and school systems have increased their graduation requirements, including those for mathematics and science.**
- ♦ **Students are taking more science and mathematics courses in high school than their counterparts did in the past.** In 1998, high school graduates earned an average of 3.5 mathematics credits and 3.2 science credits compared with 2.6 and 2.2 credits, respectively, in 1982.
- ♦ **The proportion of high school graduates completing advanced mathematics and science coursework also increased over this period.** More students have been taking algebra in grade 8, better preparing them for more advanced coursework later in high school.

Curriculum Standards and Statewide Assessments

- ♦ **The No Child Left Behind (NCLB) Act of 2001 requires states to immediately set standards in mathematics and reading/language arts, and to set standards in science by academic year 2005. By 2002, nearly all states had established standards in these three subjects.**
- ♦ **Building on the testing requirements included in the 1994 reauthorization of the Elementary and Secondary Education Act, the NCLB Act requires periodic assessments in mathematics and science and mandates consequences for poor school and student performance.** States have developed a range of rewards, supports, and sanctions based on student test scores.

Curriculum and Instruction

- ♦ **Analyses of U.S. textbooks and curricula in science and mathematics indicate that more topics are covered, and with less coherence, in the United States than in other countries.** U.S. textbooks are longer and cover more topics, but do not generally cover topics more thoroughly, and the curricula often repeat content over more grades.
- ♦ **According to a 1995 TIMSS video study, U.S. mathematics lessons generally scored lower on various measures of lesson difficulty than lessons in some other countries, notably Japan.** However, a 1999 TIMSS-R video study, which did not include Japan, found that lesson difficulty in the U.S. was comparable to that in the five other countries that participated.

Teacher Quality

- ♦ **Some evidence suggests that college graduates who enter the teaching profession tend to have weaker academic skills.** Data from the 2001 Baccalaureate and Beyond Longitudinal Study indicate that recent college graduates who taught or prepared to teach were underrepresented among graduates with college entrance examination scores in the top quartile.

- **Teaching *out of field* (teachers teaching subjects outside their areas of subject-matter training and certification) is not uncommon.** In academic year 1999, 9 percent of public high school students enrolled in mathematics classes, 10 percent enrolled in biology/life sciences classes, and 16 percent of students enrolled in physical sciences classes received instruction from teachers who had neither certification nor a major or minor in the subject they taught. Comparable figures for public middle school students were higher.
- **The proportion of relatively new teachers is slightly higher in science and mathematics than in other subjects.** Research indicates that inexperienced teachers are generally less effective than more senior teachers.
- **High-poverty and high-minority schools both had a higher proportion of inexperienced science teachers than low-poverty and low-minority schools.** Moreover, these teachers were less likely than other new science teachers to participate in induction programs, which might help them adjust to their new responsibilities. Neither of these findings held true in mathematics, however.

Teacher Induction, Professional Development, and Working Conditions

- **A large majority of new mathematics and science teachers in public middle and high schools reported that they felt well prepared to teach mathematics and science in their first year of teaching.** Teachers who participated in induction and mentoring programs were even more likely to feel well prepared.
- **In recent years, beginning teachers' salaries have risen at a faster rate than the salaries of all teachers.** However, beginning teachers receive substantially lower salaries than the average starting salary offered to new college graduates in other occupations. In academic year 1999, salaries for mathematics and science teachers were similar to those for other teachers. Mathematics and science teachers in high-poverty public high schools earned less than their counterparts in low-poverty schools.

Information Technology in Schools

- **Almost all students now study in schools and classrooms with computers and at least some form of Internet access.** By fall 2001, an estimated 99 percent of public schools and 87 percent of instructional rooms had Internet connections. This represents a dramatic increase over 1994, when the comparable figures were 35 and 3 percent, respectively. Continuing differences in school access for students in different demographic groups concern student-computer ratios, teacher preparation for using information technologies (IT), and ways in which teachers use IT. These issues go beyond mere access to encompass quality and effectiveness in IT use.
- **Teachers cite inadequate teacher training as one barrier to effective IT use but rate other barriers as equally important.** These other barriers included lack of release time, lack of scheduled time for students to use computers, insufficient computers, lack of good instructional software, outdated computers with slow processors, and difficulty accessing the Internet connection. New teachers felt better prepared to use IT than did their more experienced colleagues.
- **Students' access to computers and the Internet at home is much more unequally distributed than their access at school.** According to 2001 data, home access to computers is nearly universal among children ages 10 to 17 in the highest income category, but limited to only about one-third of children in the lowest income category. As a result, reliance on school alone for access to computers is common for children in the lowest income category, but rare in the highest income category. Racial and ethnic differences in home access to computers and the Internet are also substantial.

Transition to Higher Education

- **The percentage of high school graduates who enrolled in postsecondary education immediately after graduation increased from 47 percent in 1973 to 62 percent in 2001.** The immediate enrollment rate increased more for females than for males, and more for blacks than for whites. Rates for Hispanics remained relatively constant between 1973 and 2001, resulting in a widening gap between Hispanics and whites.
- **Many college freshmen apparently lack adequate preparation for higher education; thus, remedial coursetaking is widespread, especially at 2-year institutions**. In 2000, undergraduate enrollment in remedial classes accounted for 12 percent of mathematics enrollment in 4-year institutions and 55 percent in 2-year institutions.

Introduction

Chapter Overview

Increasingly, nations need a skilled, knowledgeable workforce and a citizenry equipped to function in a complex world. Competent workers and citizens, in turn, need a sound understanding of science and mathematics; elementary and secondary schools are responsible for ensuring that they acquire this knowledge. Yet in the United States in recent decades, few parents, policymakers, legislators, or educators have been satisfied with student achievement in mathematics and science. This dissatisfaction has spawned numerous efforts to reform and improve schools.

Twenty years have passed since *A Nation At Risk* urged higher academic standards, better teacher preparation, and greater accountability for schools as ways of improving student achievement (National Commission on Excellence in Education 1983). Other reports and commissions subsequently set ambitious goals, among them that U.S. students would rank “first in the world in mathematics and science achievement by the year 2000” (U.S. Department of Education 1989). When 2000 arrived, another national commission concluded that U.S. students were “devastatingly far from this goal” (National Commission on Mathematics and Science Teaching for the 21st Century 2000).

Seeking to give school reform efforts new momentum, the Federal No Child Left Behind (NCLB) Act of 2001 introduced strong accountability measures for schools, requiring them to demonstrate progress in boosting student achievement. (This act became law in 2002.) The act specifies steps that states must take and timelines for their implementation; these steps included immediate development of standards for mathematics and development of standards for science by academic year 2005. (Academic year 2005 refers to the school year that begins in fall 2005.) The NCLB Act also requires school districts to assess student performance every year in grades 3 through 8, beginning in academic year 2005 for mathematics and in academic year 2007 for science. Schools that do not demonstrate progress in improving achievement for all students will initially receive assistance, but they subsequently will be subject to sanctions if they still fail to show improvement.

Chapter Organization

This chapter presents data on the developments, trends, and conditions that affect the quality of U.S. elementary and secondary mathematics and science education. It begins by summarizing the most recent available information on U.S. student achievement. The chapter then examines data on aspects of the education system thought to be linked to student performance, including course offerings, coursetaking, statewide curriculum standards, accountability systems, and instructional practices.

Because of the critical role that teachers play in helping students meet high standards, the chapter also reviews data on mathematics and science teachers, including their academic ability, education, preparation, and experience; participation in teacher induction and professional development activities; salary levels; and working conditions.

The widespread use of computers and the Internet is changing education. This chapter therefore examines indicators of student and teacher access to information technologies (IT) at school and IT use in the classroom. And finally, it reviews data on high school students’ transition into higher education and the prevalence of remedial education at the college level, a discussion that leads into the examination of college-level S&E in chapter 2.

Although this chapter focuses on overall patterns, it also looks at variation in access to education resources by school poverty level and minority concentration, and in performance by sex, race/ethnicity, and family background, when such data exist. In the conclusion, we bring together these data in summary form.

Student Performance in Mathematics and Science

Available data on U.S. student performance in mathematics and science present a mixed picture. Although data show some overall gains in achievement, most students still perform below levels considered proficient or advanced by a national panel of experts. Furthermore, sometimes substantial achievement gaps persist between various U.S. student subpopulations, and U.S. students continue to do poorly in international comparisons, particularly in the higher grades. This section describes long-term trends based on curriculum frameworks developed in the late 1960s, recent trends based on frameworks aligned more closely with current standards, and the performance of U.S. students relative to their peers in other countries.

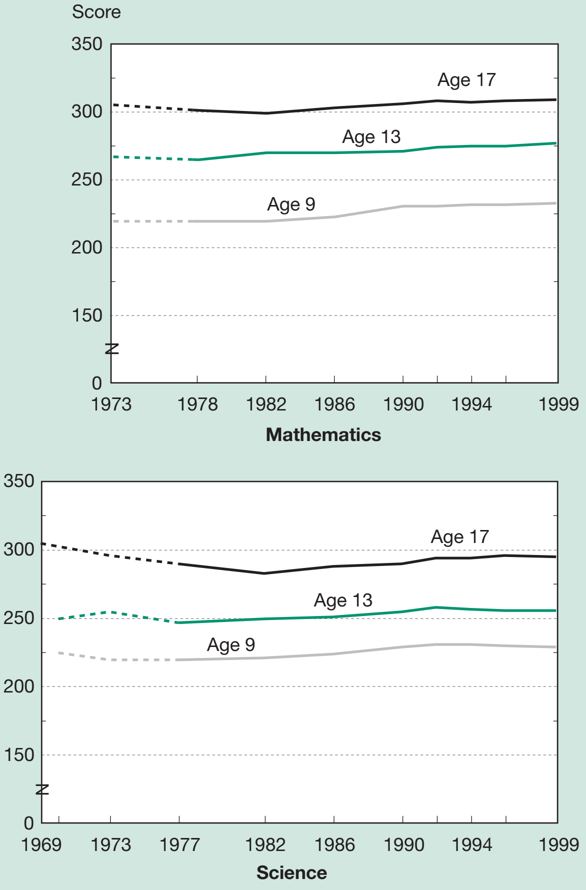
The National Assessment of Educational Progress (NAEP), also known as “The Nation’s Report Card,” has charted U.S. student performance for the past 3 decades (Campbell, Hombo, and Mazzeo 2000) and is the only nationally representative, continuing assessment of what students know and can do in a variety of academic subjects, including reading, writing, history, civics, mathematics, and science. NAEP consists of three separate testing programs. The “long-term trend” assessment of 9-, 13-, and 17-year-olds has remained substantially the same since it was first given in mathematics in 1973 and in science in 1969, and it thereby provides a good basis for analyzing achievement trends. [More detailed explanations of the NAEP long-term trend study are available in *Science and Engineering Indicators – 2002* (National Science Board 2002) and at http://www.nces.ed.gov/naep3/mathematics/trends.asp.] A second testing program, the “National” or main NAEP, is based on more contemporary standards of what students should know and be able to do in a subject. It assesses students in grades 4, 8, and 12. A third program, “state” NAEP, is similar to national NAEP, but involves representative samples of students from participating states. The NAEP data summarized here come from the long-term trend assessment and the national NAEP. Chapter 8 covers the considerable variation by state.

The most recent NAEP long-term trend assessment took place in 1999. Because the 1999 NAEP data have already been reported widely (including in the 2002 version of this report), this chapter only summarizes the main findings.

Trends in Mathematics and Science Performance: Early 1970s to Late 1990s

The NAEP trend assessment shows that student performance in mathematics improved overall from 1973 to 1999 for 9-, 13-, and 17-year-olds, although not at a consistent rate across the 3 decades (Campbell, Hombo, and Mazzeo 2000) (figure 1-1). In general, declines occurred in the 1970s, followed by increases in the 1980s and early 1990s and relative stability since that time.[1] The average performance of 9-year-olds held steady in the 1970s, increased from 1982 to 1990, and showed additional modest increases after that. For 13-year-olds, average scores improved from 1978 to 1982 with additional improvements in the 1990s. The average performance of 17-year-olds dropped from 1973 to 1982, rose from 1982 to 1992, and has since remained about the same, resulting in an overall gain from 1973 to 1999.

Figure 1-1
Trends in average scale scores in mathematics and science, by age: Selected years, 1969–99



NOTES: Student performance is assessed on a 0–500 point scale. Dashed lines represent extrapolated data. Test administration years are either labeled or are shown with tick marks.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *NAEP 1999 Trends in Academic Progress: Three Decades of Student Performance*, NCES 2000-469 (Washington, DC: U.S. Department of Education, 2000).

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Average student performance in science also improved from the early 1970s to 1999 for 9- and 13-year-olds, although again, not consistently over the 3 decades. Achievement declined in the 1970s and increased in the 1980s and early 1990s, holding relatively stable since that time. By 1999, increases had overcome the declines of the 1970s. In 1999, 9-year-olds' average performance was higher than in 1970. Among 13-year-olds, average performance in 1999 was higher than in 1973 and essentially the same as in 1970. By 1999, 17-year-olds had not recouped decreases in average scores that took place during the 1970s and early 1980s. This resulted in lower performance in 1999 than in 1969 when NAEP first assessed 17-year-olds in science.

The NCLB Act requires every student, regardless of poverty level, sex, race, ethnicity, disability status, or English proficiency, to meet challenging standards in mathematics and science. Patterns in the NAEP long-term trend data can show whether the nation's school systems are providing similar learning outcomes for all students and whether performance gaps between different groups of students have narrowed, remained steady, or grown.

Performance Trends for Males and Females

In general, the average performance of both males and females in mathematics improved from the early 1970s to the late 1990s, including the period from 1990 to 1999 (Campbell, Hombo, and Mazzeo 2000). For 9- and 13-year-olds, differences in average mathematics scores shifted from favoring females in the 1970s to favoring males by the 1990s (figure 1-2 and appendix table 1-1). Among 17-year-olds, the performance gap that favored males in 1973 had narrowed by 1999. By 1999, none of the apparent sex differences in mathematics performance were statistically significant. In science, average scores tended to favor males through 1999, although the apparent difference in 1999 for 9-year-olds was not statistically significant. The gender gap in science has remained relatively stable for 9- and 13-year olds, but it narrowed for 17-year-olds between 1969 and 1999.

Performance Trends for Racial/Ethnic Subgroups

In every racial/ethnic subgroup, a general trend of improved mathematics performance occurred over the past 3 decades. Scores for white, black, and Hispanic students, regardless of age, were higher in 1999 than in 1973 (Campbell, Hombo, and Mazzeo 2000). (Trends for other racial/ethnic groups are not reported because the samples for these

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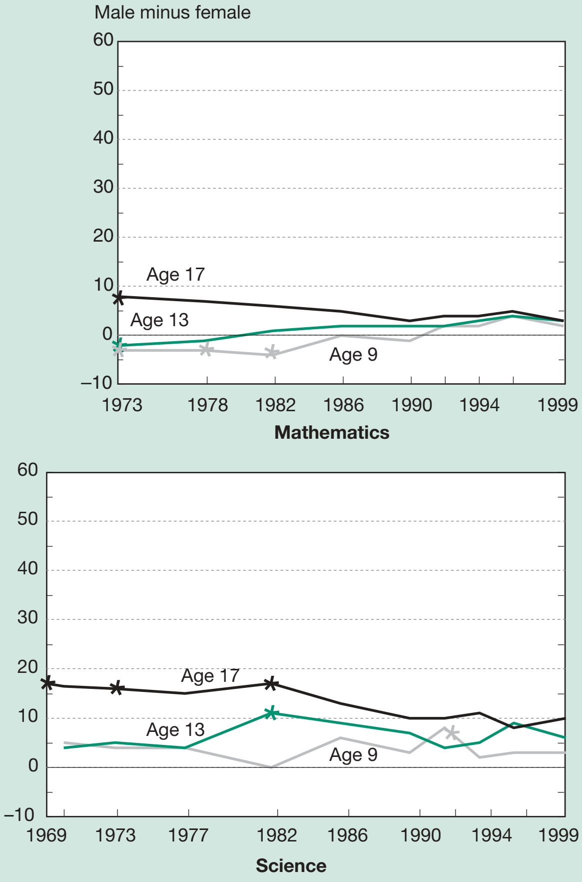
[1] The NAEP data are based on sample surveys. All trends and changes reported in this section are statistically significant at the .05 level.

Figure 1-2
Differences between male and female student average scale scores in mathematics and science, by age: Selected years, 1969–99



*Significantly different from 1999. Small differences between male and female scores are often not statistically significant. For example, the male/female differences were not statistically significant in 1999 for all three ages in mathematics and for 9-year-olds in science.

NOTES: Student performance on the long-term trend assessment is reported on a 0–500-point scale. Numbers represent the differences between males and females. Test administration years are either labeled or are shown with tick marks.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *NAEP 1999 Trends in Academic Progress: Three Decades of Student Performance,* 2000. See appendix table 1-1.

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groups are too small to analyze separately.) However, during the 1990s, although the performance of white students increased for each age group, the performance for blacks in each age group and for Hispanic 9- and 13-year-old students remained flat. The performance of Hispanic 17-year-olds increased from 1990 to 1999.

In science, scores for 9- and 13-year-olds from each racial/ethnic subgroup in 1999 were higher than in the year NAEP first assessed a particular subgroup (1970 for whites and blacks, 1977 for Hispanics) but held steady from 1990 to 1999. Among 17-year-olds, science performance trends varied. White students in that age group had lower scores in 1999 than in 1969, although the average score did increase between 1990 and 1999. The performance of black 17-year-old students was about the same in 1969, 1990, and 1999. Science scores of Hispanic 17-year-olds were higher in 1999 than in 1969 and increased from 1990 to 1999.

Despite improved performance overall from the 1970s to the late 1990s for all racial/ethnic subgroups studied, significant performance gaps persist among these subgroups (figure 1-3 and appendix table 1-2). In mathematics, the sizable gap between white and black students of all ages in 1973 narrowed until 1986 but remained relatively stable in the 1990s. Even larger performance gaps exist between white and black students in science. These gaps narrowed somewhat from 1970 to 1999 for 9- and 13-year-olds but remained essentially unchanged among 17-year-olds from 1969 to 1999. To place these gaps in perspective, in 1999 in mathematics, black students averaged about 30 points lower than did white students; in science, scores ranged from 39 to 52 points lower than those of white students, depending on the age level. These differences are roughly the same size as the differences between the average 13-year-old and 17-year-old in these subjects (figure 1-1).

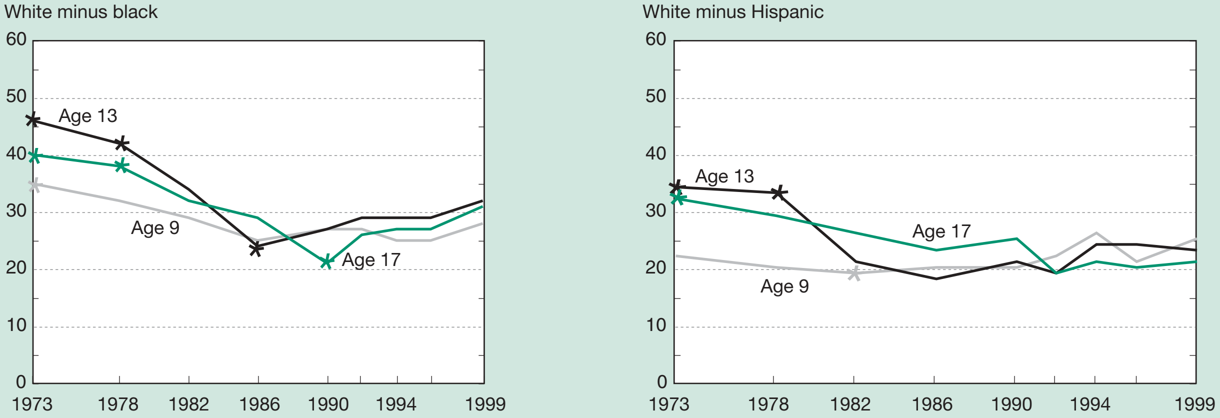
Substantial gaps also exist between Hispanic and white students at each grade level for both mathematics and science. Among 9-year-olds, the mathematics gap favoring white students widened between 1982 and 1999. Hispanic-white mathematics performance differences for 13- and 17-year-olds persist but have lessened over the past 3 decades. In science performan ce, even larger gaps exist. For 9-year-olds, the science gap did not narrow overall. The 1977 science gap for 13-year-olds narrowed during the 1980s and early 1990s, but by 1999, it had returned to nearly the 1973 level. The score difference between 17-year-old white and Hispanic youth did increase at several points in time, but by the end of the 1990s, was at the same point as in the late 1970s. The white-Hispanic differences in average scale scores in 1999 ranged from 22 to 26 points in mathematics and from 30 to 39 points in science (figure 1-3).

Racial/ethnic subgroups differ in several characteristics generally agreed to influence academic achievement. For example, black and Hispanic students' parents have less education compared with the parents of white students, and black and Hispanic students are more likely to live in poverty (Peng, Wright, and Hill 1995). Economic hardship and low education levels can limit parents' ability to provide stimulating educational materials and experiences for their children (Hao 1995; and Smith, Brooks-Gunn, and Klebanov 1997). Appendix table 1-3 illustrates the persistent achievement gaps between students whose parents have different levels of education.

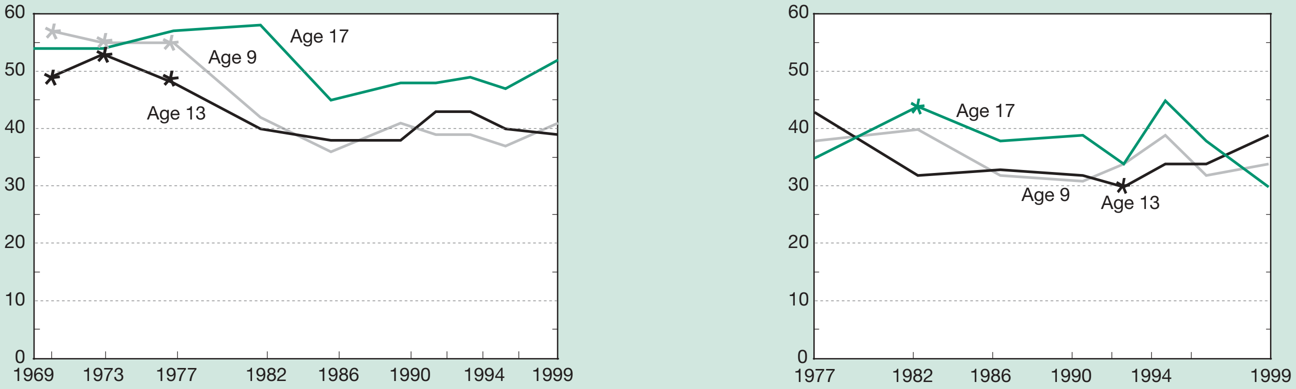
Recent Performance in Mathematics and Science

Thus far, this section has presented NAEP results based on the long-term trend assessments, which use the same items each time. The next analysis uses data from the national NAEP program, which updates instruments to

Figure 1-3
Differences between white and black student and white and Hispanic student average scale scores in mathematics and science, by age: Selected years, 1969–99



Mathematics



Science

*Significantly different from 1999.

NOTES: Student performance on the long-term trend assessment is reported on a 0–500-point scale. Numbers represent the differences between whites and blacks and whites and Hispanics. Test administration years are either labeled or are shown with tick marks.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *NAEP 1999 Trends in Academic Progress: Three Decades of Student Performance*, 2000. See appendix table 1-2.

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measure the performance of students based on more current standards. These assessments are based on frameworks developed through a national consensus process involving educators, policymakers, assessment and curriculum experts, and representatives of the public, then approved by the National Assessment Governing Board (NAGB).

NAEP first developed a mathematics framework in 1990, then refined it in 1996 (NCES 2001c).[2] It contains five broad content strands (number sense, properties, and operations; measurement; geometry and spatial sense; data analysis, statistics, and probability; and algebra and functions). The assessment also tests mathematics abilities (conceptual understanding, procedural knowledge, and problem solving) and mathematical power (reasoning, connections, and communication). Along with multiple-choice questions, assessments include constructed-response questions that require students to provide answers to computation problems or describe solutions in sentence form.

NAEP developed the science framework in 1991 and used it in the 1996 and 2000 assessments (NCES 2003c). It includes a content dimension divided into three major fields of science (earth, life, and physical) and a cognitive dimension covering conceptual understanding, scientific investigation, and practical reasoning. The science assessment also relies on both multiple-choice and constructed-response test questions. A subsample of students in each school also conduct a hands-on task and answer questions related to that task.

Student performance on the national NAEP is classified according to three achievement levels developed by NAGB that are based on judgments about what students should know and be able to do. The basic level represents partial

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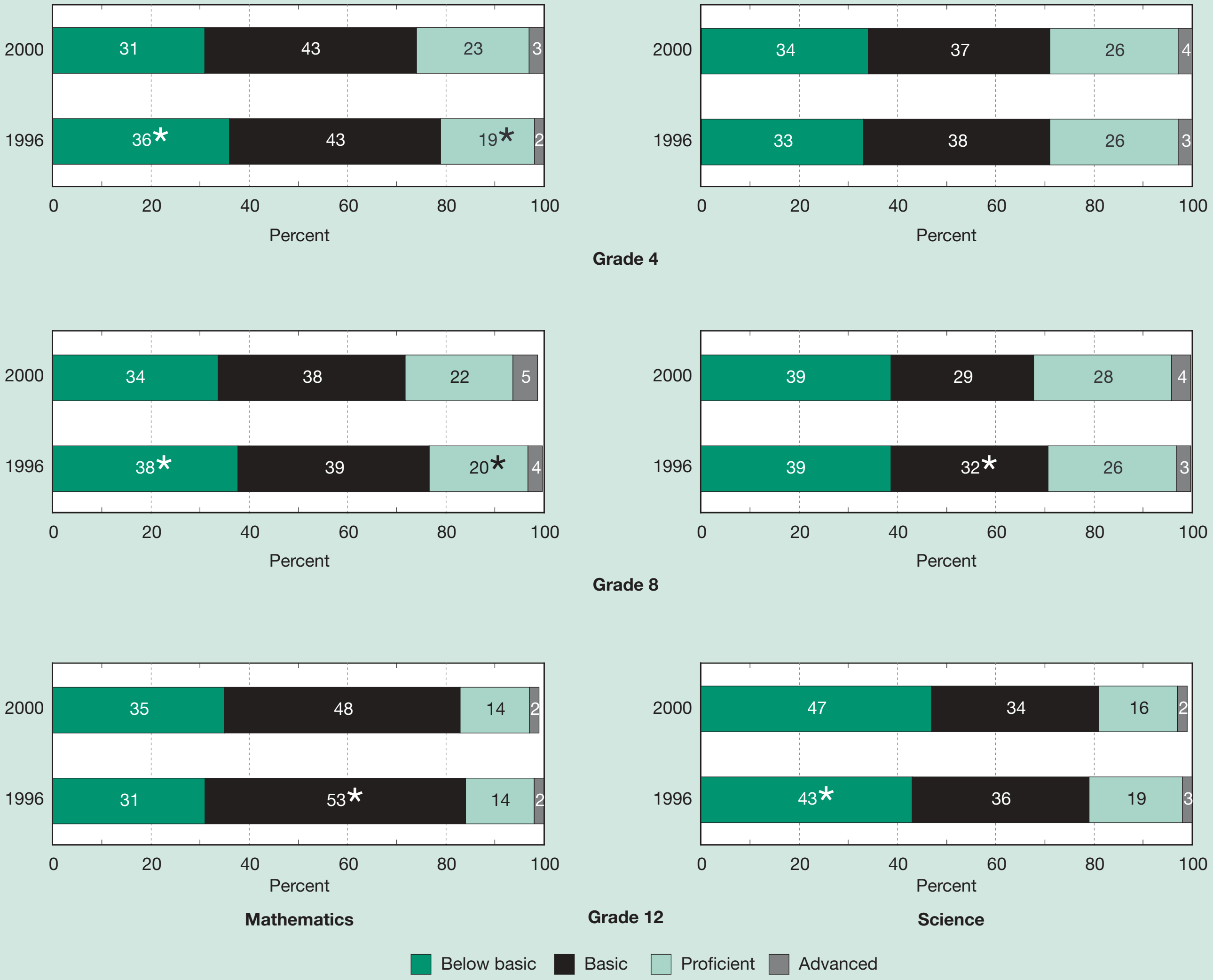
[2] The revision to the 1990 framework reflects recent curricular changes, but assessments are connected to permit trend measurement through 2003. The 2005 assessment will have a new framework.

Figure 1-4
Students within each mathematics and science achievement level range, grades 4, 8, and 12: 1996 and 2000



*Significantly different from 2000.

NOTE: Percents may not sum to 100 because of rounding.

SOURCES: U.S. Department of Education, National Center for Education Statistics (NCES), *The Nation's Report Card: Mathematics 2000,* NCES 2001-517 (Washington, DC: U.S. Department of Education, 2001); and NCES, *The Nation's Report Card: Science 2000,* NCES 2003-453 (Washington, DC: U.S. Department of Education, 2003).

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mastery of the knowledge and skills needed to perform proficient work at each grade level. The proficient level represents solid academic performance at grade level and the advanced level signifies superior performance. Disagreement exists as to whether NAEP has appropriately defined these levels, but they do provide a useful benchmark for examining recent changes in achievement.[3]

The proportion of fourth and eighth grade students reaching at least the proficient level in mathematics increased by a few percentage points from 1996 to 2000, when just over one-fourth of fourth and eighth grade students scored at or above that level (NCES 2001c) (figure 1-4). Among 12th graders, only 17 percent reached that level. Approximately one-third of students at each grade level scored below the basic level in 2000. The proportion of fourth and eighth grade students scoring below the basic level decreased from 1996 to 2000, but the proportion for 12th graders increased.

In general, the 2000 science results mirror the mathematics results (NCES 2003c). Only a minority of students reached the proficient level, and at least one-third of students at each grade level did not reach the basic level. Among 12th

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[3] A study commissioned by the National Academy of Sciences judged the process used to set these levels "fundamentally flawed" (Pellegrino, Jones, and Mitchell 1998), and NAGB acknowledges that considerable controversy remains over the setting of achievement levels (Bourque and Byrd 2000). NCES considers the achievement levels developmental and warns that they should be used and interpreted with caution (NCES 2001c). Because the levels are set by panels of experts separately by grade level and subject, meaningful comparisons across grades or subjects are not possible.

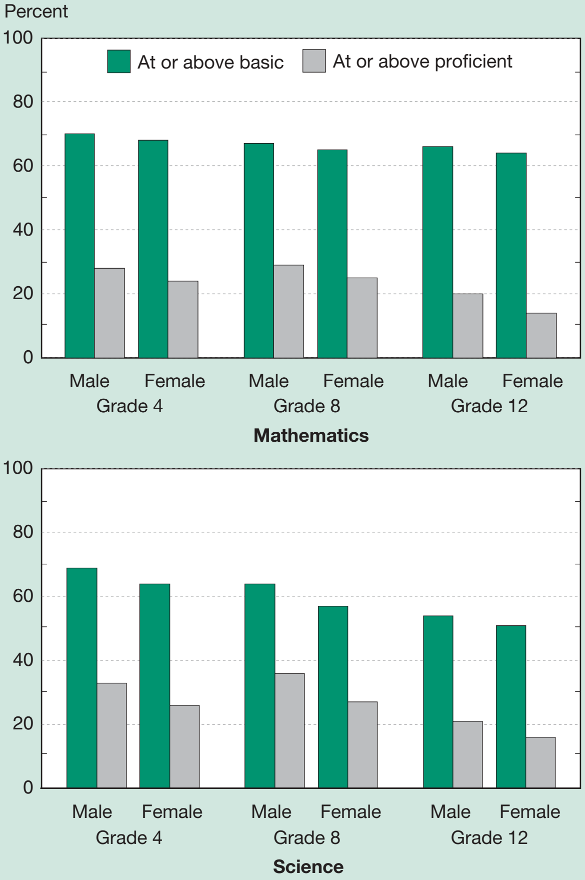
graders, that figure approached half, an increase from 1996. Across both subjects, very few students performed at the advanced level (only 2 to 5 percent).

Mathematics and Science Proficiency for Males and Females

Like the NAEP long-term assessment program, the national NAEP assessment reports results by subgroups, which allows comparisons of achievement levels among different subgroups. In 2000, similar percentages of males and females in each grade reached at least the basic level in mathematics (figure 1-5). However, more males scored at or above the proficient level. The 2000 mathematics results show improvement over 1996 for both sexes in the percentage scoring at or above the basic level in grade 4, but a decline in grade 12 (appendix table 1-4).

The 2000 science results show that a greater percentage of males than females in both grades 4 and 8 attained at least the basic level, and higher percentages of males at each grade level scored at or above the proficient level. The period between 1996 and 2000 saw no significant change in the proportion of females scoring at or above basic, or at or above proficient. Males in grade 12 registered a decline in the percentage at or above the basic level, and males in grade 8 registered an increase in the percentage at or above proficient (appendix table 1-4).

Figure 1-5
Students at or above basic and proficient levels in mathematics and science, grades 4, 8, and 12, by sex: 2000



SOURCES: U.S. Department of Education, National Center for Education Statistics (NCES), *The Nation's Report Card: Mathematics 2000*, 2001; and NCES, *The Nation's Report Card: Science 2000*, 2003. See appendix table 1-4.

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Mathematics and Science Proficiency by Racial/Ethnic Subgroups

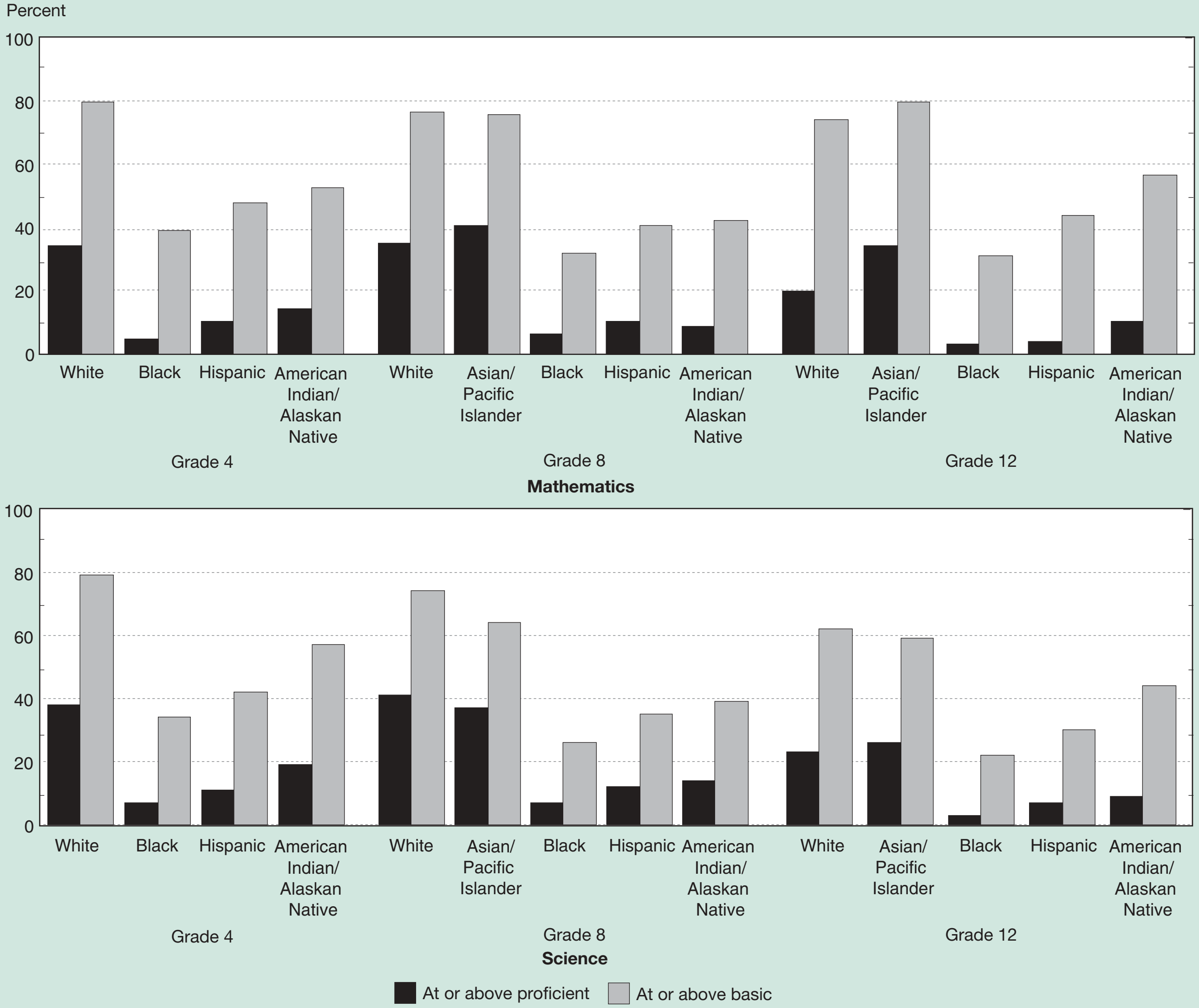
Variations in performance levels across racial/ethnic groups are more apparent than variations between males and females (figure 1-6). At each grade level in mathematics in 2000, higher proportions of white and Asian/Pacific Islander students (when scores for the latter group were reported) scored at or above the basic and proficient levels compared with black, Hispanic, and American Indian/Alaskan Native students. Among 12th grade students, 74 percent of white students and 80 percent of Asian/Pacific Islander students scored at or above the basic level compared with 31 percent of blacks, 44 percent of Hispanics, and 57 percent of American Indians/Alaskan Natives. Overall, black students had the lowest percentage scoring both at or above the basic level and at or above the proficient level. Only one statistically significant change occurred from 1996 to 2000: the proportion of white fourth grade students scoring at or above the proficient level in mathematics increased (appendix table 1-5). These differences in mathematics performance across racial/ethnic groups are evident even when children begin school (Denton and West 2002). Children from low-income and minority family backgrounds start kindergarten at a disadvantage in mathematics knowledge and skills. This disadvantage persists throughout kindergarten and into the first grade. By the first grade, black and Hispanic children are less likely than white children to solve addition, subtraction, multiplication, and division problems, and children from poor families are also less likely than those from nonpoor families to demonstrate proficiency in these areas.

Similar racial/ethnic differences hold true for science. In 2000, higher percentages of white and Asian/Pacific Islander students scored at or above the basic level and at or above the proficient level at each grade level compared with their black, Hispanic, and American Indian/Alaskan Native counterparts. Black students at all grade levels were least likely to reach these performance goals. Only one statistically significant change occurred from 1996 to 2000, a decrease in the proportion of white 12th graders reaching or exceeding the basic level (appendix table 1-5).

Mathematics Achievement in High-Poverty Schools

Poverty is negatively associated with student achievement. Analyses of NAEP 2000 mathematics data show that fourth graders in schools with higher proportions of students eligible for the Free/Reduced-Price Lunch Program, a com-

Figure 1-6
Students at or above basic and proficient levels in mathematics and science, grades 4, 8, and 12, by race/ethnicity: 2000



NOTE: Special analyses raised concerns about the accuracy and precision of the national results for Asian/Pacific Islander fourth graders in 2000; therefore, the National Center for Education Statistics (NCES) did not publish these results.

SOURCES: U.S. Department of Education, NCES, *The Nation's Report Card: Mathematics 2000*, 2001; and NCES, *The Nation's Report Card: Science 2000*, 2003. See appendix table 1-5.

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monly used indicator of poverty, tend to have lower scores (NCES 2002a) (figure 1-7).[4] This pattern occurred among eligible and not eligible students. These high-poverty schools also enrolled a greater percentage of black and Hispanic students and had higher rates of absenteeism, a lower proportion of students with a very positive attitude toward academic achievement, and lower levels of parent involvement in school activities (NCES 2002a).

International Comparisons of Mathematics and Science Performance

Two international assessment programs collected data on student performance in mathematics and science during the past decade. The 1995 Third International Mathematics and Science Study (TIMSS) involved 41 nations and studied the performance of fourth and eighth grade students as well as students in their final year of secondary school (12th grade in the United States). Four years later, a repeat study focused on the performance of eighth graders (TIMSS-R) in 38 countries. In 2000, the Program for International Student Assessment (PISA), organized by the Organisation for Economic

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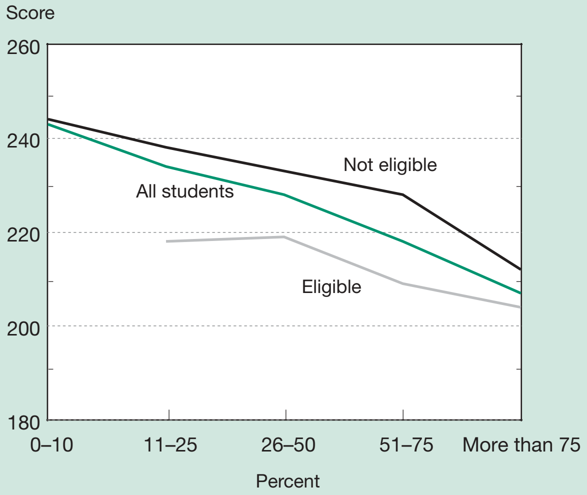
[4] Similar analyses were not conducted using the grade 8 and grade 12 data. Using participation in the Free/Reduced-Price School Lunch Program as a proxy for poverty level is not reliable at higher grades because older students may attach stigma to receiving a school lunch subsidy and choose not to participate.

Figure 1-7
Average scale scores in mathematics of fourth grade public school students, by eligibility for free or reduced-priced lunches: 2000



NOTES: Student performance is assessed on a 0–500-point scale. Sample size for the 0–10 percent group of eligible students was too small for a reliable estimate.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2002*, NCES 2002-025, Indicator 11 (Washington, DC: U.S. Department of Education, 2002).

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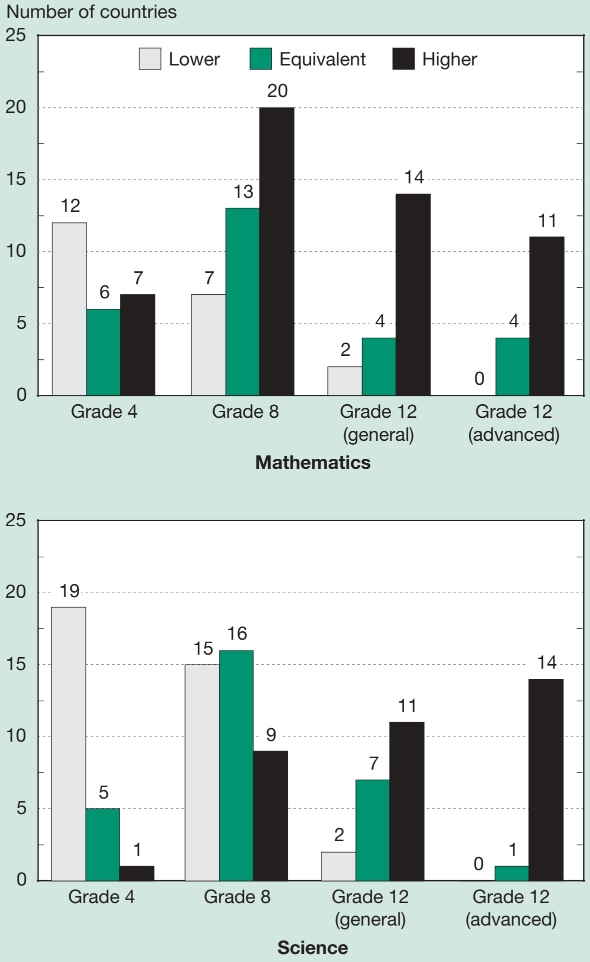
Co-operation and Development (OECD), assessed 15-year-olds from 32 countries in reading, mathematics, and science.

The design and purpose of the two assessment programs differ somewhat (Nohara 2001). TIMSS and TIMSS-R measured students' mastery of curriculum-based scientific and mathematical knowledge and skills. PISA assessed students' scientific and mathematical "literacy," with the aim of understanding how well students can apply scientific and mathematical concepts and thinking skills to real-life challenges and nonschool situations. The TIMSS and TIMSS-R findings have been reported extensively, including in the two most recent editions of *Science and Engineering Indicators* (National Science Board 2000 and 2002). Therefore, this section only briefly reviews the main findings from TIMSS and TIMSS-R, and devotes more coverage to the PISA findings.

Achievement of Fourth and Eighth Grade U.S. Students on TIMSS and TIMSS-R

In 1995, U.S. students performed slightly better than the international average in mathematics and science in grade 4, but by grade 8, their relative international standing had declined, and it continued to erode through grade 12 (figure 1-8). Of the 25 other countries participating in the fourth grade component of the assessment, 12 had lower average mathematics scores than the United States, 6 had equivalent average scores, and 7 had higher average scores. In science, 19 countries had lower scores, 5 had equivalent scores, and 1 had a higher score. Not all nations participated in every aspect of the TIMSS assessment.

Figure 1-8
Countries whose TIMSS average scores in mathematics and sciences are lower, equivalent to, or higher than U.S. average score, grades 4, 8, and 12: 1995



TIMSS Third International Mathematics and Science Study

NOTE: In the United States, the advanced mathematics assessment was administered to students who had taken or were taking precalculus, calculus, or Advanced Placement (AP) calculus; the advanced science assessment was administered to students who had taken or were taking physics or AP physics.

SOURCE: U.S. Department of Education, National Center for Education Statistics, TIMSS, 1995.

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U.S. eighth graders scored below the international average in mathematics but above the international average in science (NCES 1997b). However, nine countries outperformed the United States compared with only one in the fourth grade science assessment.

The fourth and eighth grade results from the 1995 TIMSS study suggest that U.S. students perform less well on international comparisons as they advance through school. TIMSS-R, by enabling comparisons between the relative international standing of U.S. fourth grade students in 1995 and U.S. eighth grade students 4 years later, tended to confirm this interpretation (NCES 2000b).

Achievement of 12th Grade U.S. Students on TIMSS

TIMSS assessed the mathematics and science performance of students in their final year of secondary school (12th grade in the United States).[5] It included a test of general knowledge of mathematics and science for all students and a more specialized assessment for students enrolled in advanced courses. U.S. 12th graders performed below the 21-country international average on the TIMSS test of general knowledge in mathematics and science (NCES 1998).

U.S. students taking advanced mathematics and science courses also did not fare well in comparison with their international counterparts. The advanced mathematics assessment was administered to students in 15 other countries who were taking or who had taken advanced mathematics courses and to U.S. students who were taking or who had taken precalculus, calculus, or Advanced Placement (AP) calculus. Among students who participated in the advanced assessment, U.S. students registered lower average scores compared with their international counterparts, even though the United States tends to have fewer young people taking advanced mathematics and science courses relative to other countries. A total of 11 nations outperformed the United States, and 4 nations scored similarly. No nation scored significantly below the United States.

TIMSS administered the advanced science assessment, a physics assessment, to students in 15 other countries who were taking science courses and to U.S. students who were taking or had taken physics I and II, advanced physics, or AP physics. U.S. students performed below the international average, with 14 countries having average scores higher than the United States, and 1, Australia, having an average score equivalent to that of the United States.

Mathematics and Science Literacy of U.S. 15-Year-Olds on PISA

OECD first conducted PISA in 2000 and plans two additional assessments at 3-year intervals (NCES 2001d). Although PISA 2000 concentrated on reading, it did include some mathematics and science items.

PISA aims to measure how well equipped students are for the future by emphasizing items that have a real-world context. (See sidebar "Sample Mathematics and Science Items From PISA.")

In both mathematics and science literacy, U.S. student performance did not differ from the average performance of students in the other OECD countries (appendix tables 1-6 and 1-7). Of the seven countries that had significantly higher average science scores, all also had higher average mathematics scores (Australia, Canada, Finland, Japan, New Zealand, South Korea, and the United Kingdom). In addition, Switzerland significantly outperformed the United States in mathematics. A common set of six countries had average scores significantly lower than the United States in both mathematics and science: Brazil, Greece, Latvia, Luxemburg, Mexico, and Portugal.

Subgroup Differences in Mathematics and Science Literacy

A recent report released by the U.S. Department of Education (NCES 2001d) considers PISA score differences by sex, parents' education, parents' occupation, parents' national origin, and language spoken in the home. Findings reveal no statistically significant sex difference among U.S. 15-year-olds in mathematics. This was also true for 16 other countries that participated in PISA; however, males outperformed females in mathematics in 14 countries. In science literacy, male and female students in the United States, as in most other nations, performed equally well. This absence of sex differences in mathematics and science literacy in the United States is generally consistent with findings from the NAEP, TIMSS, and TIMSS-R assessments, all of which assess more curriculum- and school-based achievement.

PISA also collected information on parents' education levels and occupation, both of which have been linked to student achievement (Coleman et al. 1966; NCES 2000b and 2001c; West, Denton, and Reaney 2000; and Williams et al. 2000). PISA data indicate that parents' education level and occupation are more strongly associated with mathematics and science literacy in the United States than in some other countries, although links between parents' education level and student achievement existed in all PISA countries (NCES 2001d). For example, in every country, students whose parents have college degrees outperformed students whose parents did not have a high school diploma. However, in only 12 of 29 countries, including the United States, students whose parents graduated from college scored higher in science literacy than students whose parents completed high school but not college. In the remaining countries, science performance did not differ between the subgroups of students with these two levels of parental education. A stronger association between parents' occupation and student mathematics and science literacy existed in the United States compared with some other PISA countries. In Finland, Iceland, Japan, Latvia, and South Korea, the relationship between parents' occupation and mathematics and science literacy was smaller than it is the United States; for mathematics, the relationship was also smaller in Canada and Italy. No country had a stronger relationship than the United States between parents' occupation and student performance on PISA's mathematics and science portions.

Students who are foreign born or who have foreign-born parents face challenges in adjusting to a new country and a

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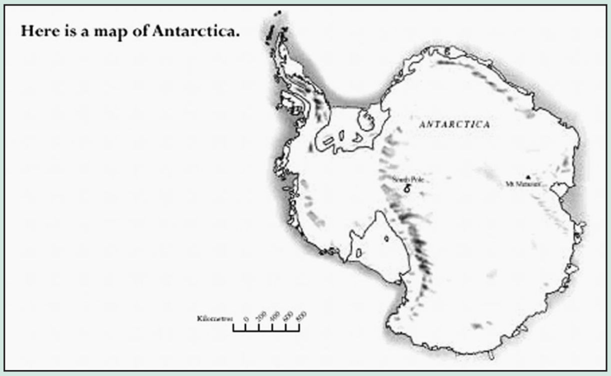
[5] NAEP has identified problems related to testing 12th grade students (NCES 2001c). Compared with students in fourth and eighth grades, they are less likely to participate, more likely to omit responses, and much less likely to indicate that they thought it either important or very important to do well on the test. If students do not try their best, NAEP may underestimate their achievement. Whether similar patterns exist in other countries is not known.

Sample Mathematics and Science Items From PISA

The examples below were included in the 2000 Program for International Student Assessment (PISA) mathematics and science assessment and include the item's level of difficulty and the proportion of both U.S. students and all students who received either full or partial credit.

Mathematics (level 3)



Directions: Estimate the area of Antarctica using the map scale.

Show your work and explain how you made your estimate. (You can draw over the map if it helps you with your estimation).

Difficulty level: middle-to-highest

Scoring: Students who provided the correct answer, between 12,000,000 and 18,000,000 square kilometers, received full credit. Students received partial credit if they showed evidence of using a correct method, such as drawing a square or circle to estimate the area, but provided an incorrect answer.

Proportion received full credit:

All OECD students: 20

U.S. students: 10

Proportion received partial credit:

All OECD students: 40

U.S. students: 38

Science (level 3)

Directions: Read the following section of an article about the ozone layer.

The atmosphere is an ocean of air and a precious natural resource for sustaining life on the Earth. Unfortunately, human activities based on national/personal interests are causing harm to this common resource, notably by depleting the fragile ozone layer, which acts as a protective shield for life on the Earth. Ozone molecules consist of three oxygen atoms, as opposed to oxygen molecules, which consist of two oxygen atoms. Ozone molecules are exceedingly rare: fewer than 10 in every million molecules of air. However, for nearly a billion years, their presence in the atmosphere has played a vital role in safeguarding life on Earth. Depending on where it is located, ozone can either protect or harm life on Earth. The ozone in the troposphere (up to 10 kilometers above the Earth's surface) is "bad" ozone, which can damage lung tissues and plants. But about 90 percent of ozone found in the stratosphere (between 10 and 40 kilometers above the Earth's surface) is "good" ozone, which plays a beneficial role by absorbing dangerous ultraviolet (UV-B) radiation from the Sun.

Without this beneficial ozone layer, humans would be more susceptible to certain diseases due to the increased incidence of ultraviolet rays from the Sun. In the last decades the amount of ozone has decreased. In 1974 it was hypothesized that chlorofluorocarbons (CFCs) could be a cause for this. Until 1987, scientific assessment of the cause-effect relationship was not convincing enough to implicate CFCs. However, in September 1987, diplomats from around the world met in Montreal (Canada) and agreed to set sharp limits to the use of CFCs.

Directions: At the end of the text, an international meeting in Montreal is mentioned. At that meeting lots of questions in relation to the possible depletion of the ozone layer were discussed. Two of those questions are given in the table below.

Can the questions listed below be answered by scientific research?

Circle Yes or No for Each

Question:	Answerable by scientific research?
Should the scientific uncertainties about the influence of CFCs on the ozone layer be a reason for governments to take no action?	Yes/No
What would the concentration of CFCs be in the atmosphere in the year 2002 if the release of CFCs into the atmosphere takes place at the same rate as it does now?	Yes/No

Difficulty level: lowest-to-middle

Scoring: Students who answered no to the first question and yes to the second question received full credit. All other answers received no credit, including those that answered only one question correctly.

Proportion received full credit:

All OECD students: 59

U.S. students: 64

SOURCES: NCES 2001d and OECD 2001.

new school system. According to PISA data, approximately 13 percent of U.S. students have parents who were both born outside the United States. In about half of the participating countries that reported this data (15 of 26), including the United States, students whose parents were both native-born scored significantly higher in mathematics. In the United States, no difference in science literacy by parent nativity existed, although differences did exist in 17 of 26 participating countries.

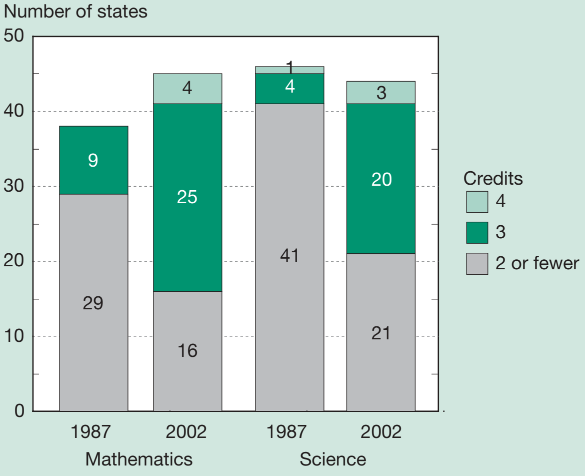
U.S. schools educate many students who speak a language other than English at home. In 19 of the 28 nations that reported data on students' home language, including the United States, students who spoke the language of the assessment at home scored better in mathematics literacy than students who did not. U.S. students registered a greater difference in mathematics performance by home language than the average OECD difference. In science, in 21 of 28 participating nations, including the United States, students who spoke the language of the assessment at home scored better than those who did not. Many PISA items impose a fairly high reading (and sometimes writing) load, which contributes to home language effects.

Mathematics and Science Coursework and Student Achievement

A Nation At Risk attributed the disappointing performance of U.S. students, in part, to "extensive student choice" in high school coursetaking (National Commission on Excellence in Education 1983). The report called for strengthened curricular requirements and graduation standards. In subsequent years, many states and school systems increased their graduation requirements (Blank and Engler 1992 and Clune and White 1992), including requirements for mathematics and science (figure 1-9). In addition to specifying the number of courses students must complete to graduate, some states also introduced requirements for particular courses, most commonly algebra, biology, and physical sciences (CCSSO 2002).

Increases in student coursetaking in mathematics and science followed. (See sidebar "Requirements and Coursetaking.") High school graduates now earn more mathematics and science credits overall and take more advanced courses.[6] When students complete challenging courses, their overall achievement improves. (See sidebar "Coursetaking and Achievement.")

Figure 1-9
Mathematics and science credit requirements for high school graduation: 1987 and 2002



NOTE: Totals do not sum to the number of states because some have no requirement or leave decisions to local districts.

SOURCES: U.S. Department of Education, National Center for Education Statistics, *Digest of Education Statistics 1987,* ED 282 359 (Washington, DC: U.S. Department of Education, 1988); and Council of Chief State School Officers, *Key State Education Policies on PK–12 Education: 2002* (Washington, DC, 2002).

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This section looks at overall coursetaking patterns with a specific look at early enrollment in algebra. It then examines patterns in advanced course offerings and in students' advanced coursetaking behavior.

Coursetaking

In 1982, high school graduates earned an average of 2.6 mathematics credits and 2.2 science credits (1 credit equals 1 year of a daily 1-hour course). By 1998, those numbers grew to 3.5 and 3.2 credits, respectively (NCES 2001a). This expansion of academic coursetaking included all racial/ethnic groups and both male and female students.

Requirements and Coursetaking

Increasing requirements appears to affect coursetaking behavior, especially among lower achieving students. Clune and White (1992) examined the coursetaking patterns of graduates from high schools that enrolled mostly lower achieving students and were located in four states that had adopted higher-than-average graduation standards during the 1980s. These students exhibited better academic coursetaking patterns than their peers around the nation. In schools with more demanding requirements, the average number of credits earned in academic subjects increased, as did the average difficulty level of the classes. Research by Chaney, Burgdorf, and Atash (1997) using NAEP data suggests that more demanding requirements have a greater impact on coursetaking by lower achieving students than on coursetaking by higher achieving ones. Students with low grade-point averages were more likely to take geometry, algebra, physics, and chemistry if they attended a school that required 3 credits in science, whereas coursetaking among high achievers was not related to schools' graduation requirements.

The National Education Commission on Time and Learning (1994) found that minority and at-risk students did fail more courses after the introduction of stronger graduation requirements. Other studies found that increasing requirements led to students taking more academic courses, but increases in coursetaking in advanced courses were not as great as those in introductory or basic courses (Blank and Engler 1992; Chaney, Burgdorf, and Atash 1997; Clune and White 1992; and Finn, Gerber, and Wang 2002).

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[6] In drawing conclusions from transcript data, one must keep in mind the fact that courses with the same titles may vary considerably from school to school in terms of content and demand on the student.

Coursetaking and Achievement

The association between coursetaking and achievement has been well documented (Campbell, Hombo, and Mazzeo 2000; Chaney, Burgdorf, and Atash 1997; Cool and Keith 1991; Hoffer, Rasinski, and Moore 1995; NCES 2001c and 2003b; Rock and Pollack 1995; and Schmidt et al. 2001). A 1995 study that analyzed data from the National Education Longitudinal Study (NELS) and that controlled for student background characteristics reported a positive relationship between the total number of mathematics and science courses completed and gains in achievement test scores from grade 8 to grade 12 (Hoffer, Rasinski, and Moore 1995). Other studies that also use the NELS data report similar findings; for example, see Lee, Croninger, and Smith 1997.

Completion of advanced coursework may be more important than completion of a greater number of courses. Students who complete higher level mathematics and science courses have, on average, higher achievement scores in these subjects. Studies that controlled for prior achievement indicate that the association does not simply result from stronger students selecting (or being selected for) the more demanding courses. Meyer (1998) found that taking advanced mathematics courses led to achievement gains for all students on assessments conducted as part of the High School and Beyond Study of 1980 high school sophomores, including college-bound and non-college-bound students and students with varying levels of mathematics skills. On the other hand, lower level courses contributed little to students' mathematics performance.

The benefits of completing advanced mathematics and science courses extend beyond improved test scores to include success in both postsecondary education and the labor force. Analyzing the High School and Beyond data, which were derived from tracking a national sample of 1980 10th graders for 13 years, Adelman (1999) found the rigor of students' high school curricula to be the best predictor of earning a bachelor's degree, and the best indicator of curriculum rigor was the most advanced mathematics course taken. Finishing a course beyond algebra II in high school more than doubled the odds that a student who entered postsecondary education would complete a bachelor's degree. Among students who successfully completed rigorous mathematics courses, race/ethnicity and socioeconomic status had little or no impact on their likelihood of completing college.

A recent study examined the relationship between advanced mathematics coursework and earnings 10 years after high school graduation (Rose and Betts 2001). The findings revealed a positive association only partly explained by the ultimate level of education attained. The authors credited cognitive gains from studying higher level mathematics with making students more productive, speculating that students "learn how to learn" from advanced mathematics coursework.

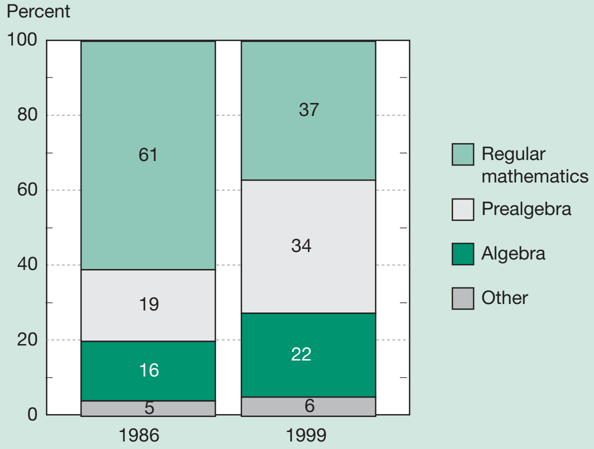
The proportion of high school graduates completing advanced mathematics and science coursework also increased over this period. From 1982 to 1998, the percentage of students completing at least one advanced mathematics course (defined as more challenging than algebra II or geometry) grew from 26 to 41 percent. In science, the proportion completing at least one advanced course (defined as more challenging than general biology) increased from 35 to 62 percent.

Algebra is considered a *gatekeeper* course for the more advanced mathematics and science courses (Oakes et al. 1990; and Schneider, Swanson, and Riegle-Crumb 1998). Compared with their peers who do not take algebra in grade 8, students who begin studying algebra during that year are more likely to complete algebra III, trigonometry, and calculus (Atanda 1999).

NAEP data indicate that the proportion of students who take algebra early increased between 1986 and 1999 (figure 1-10). In 1986, 16 percent of 13-year-olds enrolled in algebra and an additional 19 percent enrolled in prealgebra; by 1999, these figures had risen to 22 and 34 percent, respectively.

Nevertheless, a study using TIMSS data showed that about 20 percent of 1995 U.S. eighth graders attended schools that offered none of the more challenging eighth grade mathematics courses: enriched mathematics, prealgebra, algebra, or geometry (Cogan, Schmidt, and Wiley 2001). One in three eighth graders in the United States attended schools that did not offer them an algebra class. Lack of access to rigorous coursework likely has negative effects on achievement. Two measures of the difficulty of a mathematics class (time spent on various topics and combining the challenges posed by course content and textbook content) were both positively related to students' average

Figure 1-10
Distribution of 13-year-olds, by type of mathematics course: 1986 and 1999



NOTES: Numbers for 1986 are significantly different from 1999. Percents may not sum to 100 because of rounding.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, Long-Term Assessment, 1999.

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TIMSS assessment score in this study (Cogan, Schmidt, and Wiley 2001).

In the nation as a whole, enrollment size and concentration of minority students were both related to students' access to challenging mathematics content: more eighth graders had access to three of the more difficult mathematics courses (enriched mathematics, prealgebra, and algebra) as the size of eighth grade enrollment increased and as the percentage of minorities in the school decreased.

Advanced Mathematics and Science Courses Offered in High Schools

Student coursetaking is constrained by the courses schools offer. Advanced courses are not equally available in all schools. Oakes et al. (1990) reported that as the proportion of low-income and minority students increased, the relative proportion of college preparatory and advanced courses decreased. For example, schools serving students from primarily high-income families offered approximately four times the number of sections of calculus per student as schools serving large proportions of students from low-income families.

The 1990, 1994, and 1998 NAEP assessments collected information on the courses high schools offered (appendix tables 1-8 and 1-9). Much larger percentages of graduates attended schools that offered advanced courses compared with the proportion of graduates who actually completed these courses. For example, although 86 percent of 1998 graduates attended schools that offered calculus, only 12 percent of graduates completed it (appendix tables 1-8 and 1-10). Compared with 1990, greater percentages of graduates in 1998 attended schools that offered precalculus/analysis, statistics/probability, and calculus.[7] Schools did not widely offer International Baccalaureate (IB) precalculus or AP statistics courses, but the majority (64 percent) of students could take AP/IB calculus courses. (The AP and IB programs provide students in participating high schools with advanced coursework across a variety of subjects, allowing them to potentially earn college credit while in high school. Starting in 1998, AP and IB coursetaking were reported separately by the National Center for Education Statistics.)

Precalculus/analysis and AP/IB calculus courses were more commonly available to students in urban and suburban than in rural schools. Course offerings in precalculus/analysis, calculus, and AP/IB calculus tended to increase as student enrollment increased. Significant differences in course offerings by school poverty level occurred only for precalculus and statistics/probability.

Advanced science courses were more widely available than advanced mathematics courses (appendix tables 1-8 and 1-9). In 1990, 1994, and 1998, more than 90 percent of high school graduates attended schools that offered advanced biology, chemistry, and physics, or all three. High schools attended by 27 percent of 1998 graduates offered AP/IB physics, schools attended by 39 percent offered AP/IB chemistry, and schools attended by 46 percent offered AP advanced biology.

Despite an overall prevalence of advanced science offerings, availability varied by school characteristics. Students attending urban and suburban schools were more likely to be offered advanced science courses, particularly AP/IB courses compared with students in rural schools. However, there was no statistically significant difference in chemistry offerings by location or in physics offerings for students in rural schools compared with suburban ones. School size was related to offerings for all seven advanced science categories, with the likelihood of attending a school offering advanced courses rising with school size. A particularly pronounced association occurred in the AP/IB categories. In AP/IB chemistry and AP/IB physics, a link existed with school poverty, with students in low-poverty schools more likely to be offered these courses.

Advanced Mathematics and Science Coursetaking in High School

In the 1990s, as more high schools offered more courses, students increased their advanced coursetaking in mathematics. (Mathematics courses considered "advanced" include trigonometry/algebra III, precalculus/analysis, statistics/probability, and calculus.) In conjunction with the 12th grade NAEP assessments, the National Center for Education Statistics collected information on courses completed by 1990, 1994, and 1998 high school graduates. In 1998 (compared with 1990), larger proportions of students completed precalculus/analysis (23 versus 14 percent), statistics/probability (4 versus 1 percent), and calculus (12 versus 7 percent) (appendix table 1-10).

Only a few students completed AP/IB courses. For example, in 1998, only 6 percent of high school graduates completed an AP/IB calculus course. Male and female graduates were equally likely to have taken advanced mathematics courses in high school, including AP/IB courses. However, considerable racial/ethnic differences existed in advanced mathematics course participation. In general, Asians/Pacific Islanders were most likely to take advanced courses, followed by whites, then blacks and Hispanics; the latter two groups exhibited similar advanced coursetaking patterns (appendix table 1-10).

Advanced course participation also varied by type of school attended. High school graduates from urban and suburban schools were more likely to complete precalculus and AP/IB calculus than students from rural schools, but no significant differences existed by school location for the remaining categories of advanced mathematics courses. Course participation in AP/IB calculus was higher in medium and large schools than small ones, but participation in

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[7] Statistical weights are not available to generate national school estimates from the sample of high schools. Instead, student weights can be used to estimate what students were offered at their schools. This means, for example, that rather than report that urban schools offered more advanced mathematics courses, it would be reported that students attending urban schools were offered more advanced courses.

other course categories did not differ significantly by school size. The completion of advanced mathematics courses decreased as school poverty increased for precalculus, statistics/probability, calculus, and AP/IB calculus but not for trigonometry/algebra III.

For science, increased advanced coursetaking also occurred from the beginning of the 1990s to the end of the decade (appendix table 1-11). (Science courses considered "advanced" include advanced or AP/IB biology, any chemistry, and any physics.) Compared with 1990, larger proportions of 1998 high school graduates completed courses in advanced biology, chemistry, and physics. Relatively low participation in AP/IB science courses occurred in 1998, with 5 percent of graduates completing an AP/IB course in biology; 3 percent, one in chemistry; and 2 percent, one in physics.

In contrast to mathematics, sex differences existed in advanced science coursetaking. In 1998, female high school graduates were more likely than males to take advanced biology, AP/IB biology, and chemistry, although males were more likely to have completed a physics course (including an AP/IB course). For racial/ethnic groups, a pattern of participation existed similar to that for mathematics. Smaller proportions of blacks and Hispanics tended to complete advanced science courses compared with whites and Asians/Pacific Islanders.

Consistent with mathematics findings, high school graduates from urban and suburban schools were generally more likely than their counterparts from rural schools to have completed advanced science courses. A significant relationship with school size existed for AP/IB biology and AP/IB chemistry, with participation rising with enrollment. As school poverty increased, fewer students completed courses in chemistry and physics.

Curriculum Standards and Statewide Assessments

One response to evidence of disappointing achievement by U.S. students has been the movement—accelerating since the early 1990s—to define and implement higher standards for student learning. The National Council of Teachers of Mathematics (NCTM) issued and revised mathematics standards in 1989 and 2000 (NCTM 1989 and 2000), the American Association for the Advancement of Science (AAAS) published *Benchmarks for Science Literacy* (AAAS 1993), and the National Research Council (NRC) issued the National Science Education Standards (NSES) (NRC 1996). These standards documents recommend that schools cover fewer topics in greater depth, use inquiry-based methods, and focus on understanding of concepts in addition to basic skills. During the 1990s states used such guiding documents to develop their own standards and curriculum frameworks, to create new assessment instruments, and to reform teacher education.

This section reports on state curriculum standards and testing and accountability policies.

State Curriculum Standards and Policy on Instructional Materials

The NCLB Act requires states to immediately set standards in mathematics and reading/language arts, and to set standards in science by academic year 2005. In 2002, 49 states and the District of Columbia had content standards for mathematics (as well as for English/language arts), and 47 states had standards for science (CCSSO 2002). Many states have recently revised or are in the process of revising their standards, curriculum frameworks, and instructional materials. By 2002, exactly half the states had set a regular timeline for reviewing and modifying their standards (Editorial Projects in Education 2003).

Standards documents vary greatly in detail, degree of focus, specificity, clarity, and level of rigor. Evaluations of standards have used different criteria and methods (Achieve, Inc. 2002b; AFT n.d.; and Finn and Petrilli 2000). States also prescribe instructional materials to varying degrees. In spring 2002, 21 states had no policy prescribing textbooks and another 4 had a policy of local choice. Of states that restricted textbook choice, eight produced a list of approved books and materials for local choice, five selected textbooks, and nine combined selection and recommendation (CCSSO 2002).

Accountability Systems and Assessments

Assessment Programs in Mathematics and Science

Building on the testing requirements included in the 1994 reauthorization of the Elementary and Secondary Education Act, the NCLB Act requires all schools to conduct mathematics and reading assessments during academic year 2002 in at least one grade of three different grade spans (grades 3–5, 6–9, and 10–12). By academic year 2005, states must test students in grades 3–8 in these subjects every year and must test all students once during the grades 10–12 span. States must also conduct science assessments in one grade of the same grade spans by academic year 2007. The act prescribes rigorous assessments aligned with state standards but does give states wide latitude in setting school performance standards. The NCLB Act also requires states to participate in the NAEP assessments for the subjects in which the state tests in order to provide policymakers and the public with common benchmarks for judging the rigor of their own state's standards, assessments, and performance requirements.

By 2002, many states had already developed and administered tests based on their curriculum standards and frameworks. For example, in academic year 2002, 19 states and the District of Columbia required students to take mathematics and reading tests in the grades identified by the NCLB Act (Doherty and Skinner 2003).

The NCLB Act requires states to publish achievement data and other indicators of performance (such as attendance and completion rates) at the school level, and disaggregated by key demographic characteristics such as income, race/

ethnicity, and English proficiency status. A total of 29 states and the District of Columbia rated all schools or identified all low-performing schools in academic year 2002, but only 12 states relied solely on student test scores for these evaluations (Editorial Projects in Education 2003). The other 17 states and the District of Columbia used test scores along with other information such as attendance rates, graduation rates, and coursetaking data.

Consequences and Sanctions

Recently implemented state accountability systems differ from previous waves of reform in that they specify consequences for poor school and student performance. For students, consequences may include using test scores to determine grade promotion or retention and award high school diplomas. For districts and schools, states have developed a range of rewards, supports, and sanctions based on student test scores. In academic year 2002, 27 states and the District of Columbia provided assistance to low-performing schools (for example, funds for tutoring and additional teacher professional development) and 17 states financially rewarded schools that meet, or make sufficient progress toward, high achievement goals (Editorial Projects in Education 2003). State officials may impose sanctions on low-performing schools in 22 states and the District of Columbia. These include reconstitution (18 states and the District of Columbia), allowing students to transfer to other schools (11 states and the District of Columbia), and school closure (11 states). However, only three states permit withholding funds from schools. States do not necessarily exercise their authority to apply sanctions against schools and staff; they generally try to raise achievement in a low-performing school by first providing additional support such as targeted professional development, new instructional materials, and tutoring. Of the 30 states that identified low-performing schools in 2002, 27 provided some form of assistance to these schools (Achieve, Inc. 2002a).

Implementation Issues in Assessment

The role of standardized testing in accountability systems is controversial. Proponents of testing say it can improve achievement in at least two ways. First, it can provide information about how well educational systems are functioning and insight into where changes may be warranted. Second, accountability for test results can create incentives for students, teachers, instructional material developers, and school administrators to alter their behaviors in ways that facilitate achievement. Critics worry that, in implementing testing regimes, school systems will rely on tests that are insufficiently aligned with their standards and curricula. Such tests would measure school and student performance poorly, and strong incentives to perform well on these tests would undermine curricular priorities.

One indicator of alignment is whether tests were *customized*, or specifically designed for a state's standards and curricula. Customization provides opportunities for alignment, although it does not guarantee it. In the 2002 academic year, 31 states used only customized tests, 12 used a mix of customized tests and tests purchased from commercial publishers that develop tests for a national market, and 7 used tests that were not customized (GAO 2003). Customization will increase over time because the NCLB Act requires states to either develop tests aligned to their standards or augment commercial tests with aligned questions.

Critics also doubt that assessments, especially multiple choice examinations, will effectively measure higher-order thinking and conceptual understanding, which are key emphases in national mathematics and science standards. In the 2002 academic year, 12 states used tests composed solely of multiple-choice questions, while 36 states used tests that combined multiple-choice items with a limited number of written-response questions (GAO 2003).

Definitive data on the effects of enhanced accountability measures do not exist, but the limited studies available suggest that under some circumstances, these measures may improve student achievement (Carnoy and Loeb 2002; Raymond and Hanushek 2003; Roderick, Jacob, and Bryk 2002).

Curriculum and Instruction

Curriculum and instructional methods influence what students learn and whether they can apply knowledge and skills to new problems or applications (Schmidt et al. 2001). This section summarizes data regarding methods of teaching mathematics and science in the United States. It presents findings about textbooks, curricular content, and aspects of teachers' instructional practices and provides international comparisons when available.

Approaches to Teaching Mathematics and Science

Proponents of different curricular emphases and teaching methods, particularly in mathematics, have argued in recent years over the effectiveness of various approaches. Some emphasize computational skills and number operations, and others stress mathematical understanding and reasoning skills (Reys 2001). NRC and others have concluded that students need to develop these and other skills so that they reinforce and complement one another (Kilpatrick and Swafford 2002 and NCTM 2000). Mathematics proficiency, according to NRC, consists of five essential components, or *strands*, that should be integrated to support effective learning. These strands are:

- ♦ **Understanding.** Comprehending mathematics concepts, operations, and relations, including mathematical symbols and diagrams.
- ♦ **Computing.** Carrying out mathematical procedures (such as adding, subtracting, multiplying, and dividing numbers) flexibly, accurately, efficiently, and appropriately.

- **Applying.** Being able to formulate problems mathematically and devise strategies for solving them using concepts and procedures appropriately.
- **Reasoning.** Using logic to explain and justify a solution to a problem or extend from something known to something not yet known.
- **Engaging.** Seeing mathematics as sensible, useful, and doable when one works at it, and being willing to do the work.

Few national data exist linking curricular reforms to changes in student achievement, although some state and local studies suggest standards-based curricula that integrate a range of skills with knowledge may lead to overall higher achievement and help reduce gaps between minority and white students (Briars 2001, Mullis et al. 2001, Riordan and Noyce 2001, Schneider et al. 2002, and Schoenfeld 2002). Some research also supports the potential effectiveness of inquiry-based instruction in science, in which students learn primarily by conducting experiments to test ideas and answer questions (Amaral, Garrison, and Klentschy 2002; Stoddart et al. 2002; and Stohr-Hunt 1996).

Textbooks

Textbook content can affect teaching and learning. Systematic expert ratings of how well textbooks address nationally recognized content and curriculum standards for mathematics and science have taken place, although the available research does not include rigorous studies that relate textbook content to student achievement.

Starting in 1999, AAAS Project 2061 assigned teams of mathematics and science professors and K–12 teachers to evaluate textbooks, teachers' guides, and related instructional materials in categories based on subject and grade level. Using selected criteria from *Benchmarks for Science Literacy* (AAAS 1993), reviewers in one Project 2061 evaluation (AAAS 1999b) measured how well middle school mathematics textbooks addressed 6 central mathematics concepts/skills and how well the textbooks incorporated 24 instructional criteria consistent with NCTM standards (NCTM 1989 and 2000). Project 2061 rated 4 of the 12 textbooks it evaluated as excellent but judged the remaining 8 to be inadequate overall and merely satisfactory in teaching number and geometry skills. At the time, those eight were among the most widely used middle school mathematics texts in the United States.

Project 2061 also conducted evaluations of algebra textbooks (AAAS 2000a), middle school science materials (AAAS 1999a), and high school biology textbooks (AAAS 2000b). Overall, reviewers judged most to have deficits in teaching students many thinking skills identified by standards documents; they also lacked some content identified in subject standards. Commonly found weaknesses included emphasizing detail and terminology at the expense of core concepts (a problem more prevalent in science materials), insufficiently developing students' reasoning abilities, and providing inadequate guidance for students and teachers to discover and correct misconceptions. Reviewers also identified several common positive attributes: most materials covered content thoroughly and accurately, provided a range of applications and hands-on activities, and used inviting graphics to illustrate ideas. Project 2061 noted that some newer texts showed improvement over older ones.

The American Institute of Biological Sciences (AIBS) assessed how well 10 high school biology textbooks and related materials (Morse 2001) adhered to standards embodied in NSES. Overall ratings ranged from just below adequate to slightly below excellent. In general, AIBS concluded that the materials conveyed life science content very well but were not as effective in providing guidance for teachers and in handling certain non-life-science content. Most instructional materials received high marks for accuracy, attractive illustrations and design, and inclusion of recent developments in biology research. However, AIBS found that most were crammed with too much information and detail, placing a great burden on teachers to select priorities and make links between content areas. In addition, AIBS concluded that most materials failed to fully capitalize on current understanding about how students learn and did not provide useful assessments for tracking and advancing learning.

Reviewers rated some recently developed curriculum materials as strong in areas that rarely receive positive ratings. For example, AIBS concluded that three recently developed instructional packages incorporated the pedagogical recommendations in NSES quite well. An earlier National Science Foundation evaluation of middle school science instructional materials (NSF 1997) also identified several packages that embodied useful standards-based reforms such as organizing content around conceptual themes, emphasizing important concepts in science, balancing breadth and depth of content coverage, and providing assessments tied to instructional goals.

International data indicate that U.S. textbooks tend to address more topics than those used in other countries and to devote less attention to the five most prominent topics. They fail to build more challenging material on simpler content introduced earlier and to make clear connections among content areas (Schmidt, McKnight, and Raizen 1997). As a result, reviewers have criticized U.S. texts as typically less focused and less coherent than those used in many other countries. The data indicate striking differences in textbook length: fourth grade mathematics textbooks in the United States in 1995 averaged 530 pages, more than three times as long as the international average in TIMSS (Valverde and Schmidt 1997). Similar differences in length were found in science textbooks. This greater length results from covering more topics rather than from covering individual topics more thoroughly.

Curriculum

In addition to testing students' learning, the 1995 TIMSS study collected information at the three age and grade levels about the curriculum intended by policymakers, the curriculum that teachers taught, methods of teaching, instructional materials, students' school experiences, and demographic characteristics. TIMSS also examined eighth grade mathematics class practices in the United States, Germany, and Japan through a classroom videotape study and teacher interviews. In TIMSS-R, conducted 4 years later, the videotape component was expanded to include seven countries and to cover science as well as mathematics.[8] Analyses show differences among countries in two important aspects of the mathematics and science curriculum: breadth of coverage and lesson difficulty.

Breadth of Coverage

Consistent with findings about textbooks, research indicates that mathematics and science curricula in the United States generally cover more content areas (NCES 2000a). In eighth grade science, TIMSS-R data showed U.S. students as more likely than the international average to study four of six main content areas: earth science, biology, physics, and scientific inquiry and the nature of science (NCES 2000a).[9] For example, about 95 percent of U.S. eighth graders had received instruction on scientific inquiry before the TIMSS-R assessment compared with an 80 percent international average. The rates for studying the other five topics ranged from 70 to 81 percent in the United States compared with international averages of 53 to 72 percent. (The proportions of U.S. students who studied chemistry and environmental resource issues were comparable to the international average.)

Similarly, eighth grade mathematics classes covered many topics. Higher percentages of U.S. students received instruction in four of the five mathematics content areas in 1999: fractions and number sense; algebra; data representation, analysis, and probability; and measurement. The vast majority of U.S. students had studied these topics by the end of grade 8 (ranging from 91 to 99 percent). Only in geometry did no significant difference exist: 58 percent of eighth graders in the United States had studied that topic compared with 65 percent in other countries (NCES 2000b).

Curriculum in the United States, as observed from curriculum frameworks for both mathematics and science, repeats content across more grades than does curriculum in other countries.[10] In eighth grade mathematics, for example, U.S. curricula often continue to cover topics that no longer appear in the curricula of other nations such as number operations, fractions, percentages, and estimation (Schmidt et al. 2001; Schmidt, McKnight, and Raizen 1997; and Stevenson 1998). U.S. curriculum frameworks generally failed to build more complex content on simpler but related content covered earlier.

In addition, U.S. teachers in 1995 spent significantly less time than German or Japanese teachers on the most emphasized topics (Schmidt, McKnight, and Raizen 1997). U.S. eighth grade mathematics teachers covered 16 to 18 topics during the year with only a single topic receiving more than 8 percent of available teaching time. In Japan, teachers focused extensively on only four topics, allocating two-thirds of total classroom time to these topics (Wilson and Blank 1999). These patterns found in TIMSS reflect findings from the Second International Mathematics and Science Study in the early 1980s (McKnight et al. 1987) and suggest a structural feature of some durability in U.S. elementary and secondary education.

Lesson Difficulty

For the 1999 TIMSS-R mathematics video study, researchers developed a measure of lesson difficulty, *procedural complexity,* based on the number of steps needed to solve a problem using common methods. The measure is thus independent of a student's prior knowledge and skill (NCES 2003b). Japan stood apart from other participating nations in lesson complexity. In the United States and the other five countries, only 6 to 12 percent of problems had high complexity compared with 39 percent of problems used in Japanese lessons (figure 1-11).[11] Only 17 percent of problems in Japanese lessons addressed low-complexity problems compared with 63 to 77 percent in the other six nations. U.S. mathematics lessons did not differ significantly from those in the other five nations in the proportion of problems that had high or low complexity.

Using other measures, the 1995 TIMSS classroom video study also revealed differences in lessons' degree of challenge. Mathematics professors were asked to assign a grade level to videotaped eighth grade mathematics classes: they rated U.S. lessons on average at the seventh grade level, German lessons at the end of eighth grade, and Japanese lessons at the beginning of ninth grade (NCES 1997b). In addition, professors evaluated lesson quality based on the percentage of lessons requiring deductive reasoning by students: 0 percent of lessons in the United States, 21 percent in Germany, and 62 percent in Japan required use of deductive reasoning (Schmidt, McKnight, and Raizen 1997). Deductive reasoning, such as that used to prove a theorem, is a higher order skill that experts recommend students practice and an important component of learning in mathematics, science, and other disciplines.

TIMSS data thus portrayed U.S. eighth grade mathematics classes as rarely emphasizing logic or involving students in logical reasoning. In 1995, in U.S. mathematics lessons, teachers stated the rule students should follow to solve problems for nearly 80 percent of topics rather than explaining the rule or having students work on the reasoning. In contrast, students and teachers developed solutions using logic

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[8] TIMSS–R, limited to eighth grade, collected data from teacher and student surveys on many topics mentioned for TIMSS, although many items were new or different.

[9] A topic counted as being taught if teachers reported that they spent more than five class periods on it during the current year or that students had studied it in a previous grade.

[10] Based on a sample of state and local curriculum frameworks because the United States lacks a national curriculum.

[11] Japan did not participate in the mathematics video study in 1999. Data reported here for Japan come from the 1995 video study. TIMSS collected data from the other six nations in 1999.

(for example, proving or deriving the answer step by step) for more than 80 percent of topics covered in Japan and nearly 80 percent of topics covered in Germany (Stevenson 1998). German teachers usually proved rules for the class and Japanese teachers tended to give students the assignment of figuring out the solution's proof (NCES 1997b).

Analyzing the topics teachers prioritize provides another way to examine differences in difficulty. As figure 1-12 shows, U.S. eighth grade mathematics students in 1999 were twice as likely as the international average to be in classes where teachers placed the most emphasis on numbers and arithmetic (28 versus 14 percent), and they were three times as likely to be in classes where algebra received the most emphasis (27 versus 8 percent) (Mullis et al. 2001). In contrast, far higher percentages of other nations' eighth graders experienced a combined emphasis on algebra and geometry or on algebra, geometry, numbers, and other topics.

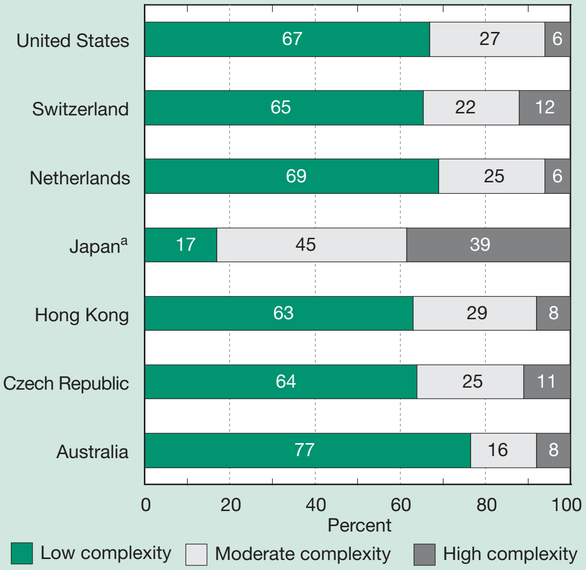
Instructional Practices

The 1999 TIMSS-R video study of mathematics classes in seven nations showed that in the United States teachers spent about half of total lesson time (53 percent) reviewing previously taught material, with the other half nearly equally divided between introducing and practicing new content (NCES 2003b) (figure 1-13). In Japan teachers spent 60 percent of class time introducing new material, more than in any of the other six countries. Although most lessons in each nation included both review and new material, U.S. teachers presented proportionally many more lessons devoted entirely to reviewing old content than did teachers in Hong Kong or Japan, two economies with particularly high scores.

In 1999, U.S. eighth graders watched the teacher demonstrate how to solve mathematics problems more often than their international peers (NCES 2000b). Compared with the international average, U.S. students were more likely to

Figure 1-11

Average percentage of eighth grade mathematics problems per lesson at each level of procedural complexity, by country/economy: 1999



[a]Data collected in 1995.

NOTES: Percents may not sum to 100 because of rounding. For each country/economy, average percent was calculated as the sum of percents within each lesson divided by the number of lessons. The margin of error varies considerably across locations so that differences of the same magnitude may be significant in some cases but not in others. Low complexity: Australia, Czech Republic, Hong Kong, Netherlands, Switzerland, United States > Japan. Moderate complexity: Hong Kong > Australia; Japan > Australia, Switzerland. High complexity: Japan > Australia, Czech Republic, Hong Kong, Netherlands, Switzerland, United States.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *Highlights From the TIMSS 1999 Video Study of Eighth-Grade Mathematics Teaching,* NCES 2003-011 (Washington, DC: U.S. Department of Education, 2003).

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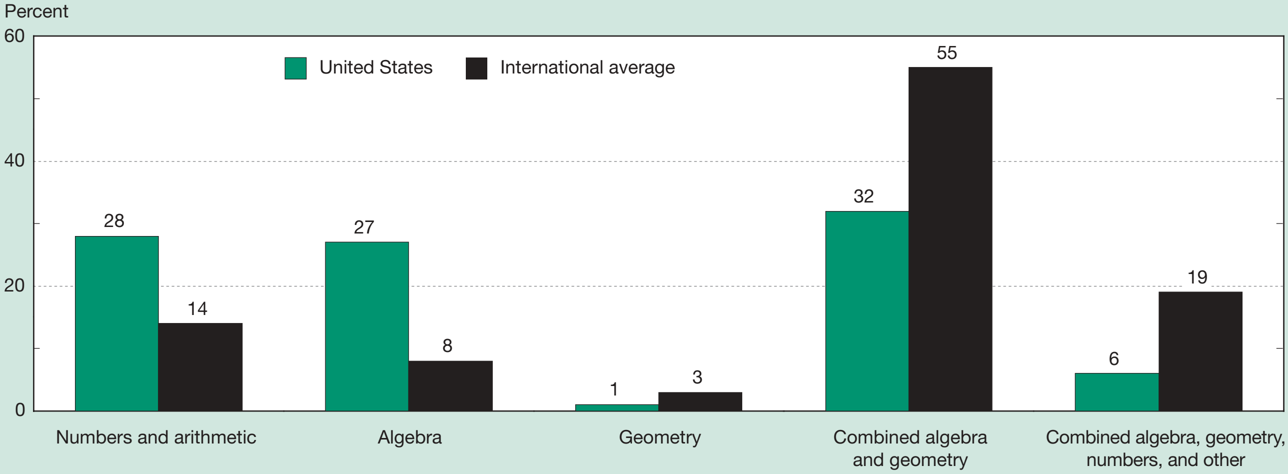
Figure 1-12

Students whose teachers reported emphasizing certain topics in eighth grade mathematics: 1999



SOURCE: I. V. S. Mullis et al., 2001, *Mathematics Benchmarking Report: TIMSS 1999–Eighth Grade. Achievement for U.S. States and Districts in an International Context* (Chestnut Hill, MA: International Association for the Evaluation of Educational Achievement and Boston College, International Study Center, 2001).

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Figure 1-13
Average percentage of eighth grade mathematics lesson time devoted to various purposes, by country or economy: 1999

[a] Data collected in 1995.

NOTES: For each country, average percent was calculated as the sum of percents within each lesson, divided by number of lessons. Percents may not sum to 100 because of rounding and the possibility of coding portions of lessons as "not able to make a judgment about the purpose." The margin of error varies considerably across locations so that differences of the same magnitude may be significant in some cases but not in others. Reviewing: Czech Republic > Australia, Hong Kong, Japan, Netherlands, Switzerland; United States > Hong Kong, Japan. Introducing new content: Hong Kong, Switzerland > Czech Republic, United States; Japan > Australia, Czech Republic, Hong Kong, Netherlands, Switzerland, United States. Practicing new content: Hong Kong > Czech Republic, Japan, Switzerland.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *Highlights From the TIMSS 1999 Video Study of Eighth-Grade Mathematics Teaching*, NCES 2003-011 (Washington, DC: U.S. Department of Education, 2003).

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work alone on mathematics worksheets or textbook problems and to use data from everyday life, but less likely to do projects in their mathematics classes. TIMSS-R also indicated that U.S. eighth grade mathematics students were more likely than the international average (54 versus 43 percent) to write equations to represent mathematical relationships in most, or every, lesson (figure 1-14). However, no significant differences existed for several other learning activities: explaining their reasoning for an answer, representing or analyzing relationships using tables and graphs, working on problems with no obvious method of solution, and practicing computation (Mullis et al. 2001). Students in all countries quite often explained their reasoning (70 percent of all teachers reported this activity in most lessons compared with 72 percent in the United States) and practiced computational skills (73 percent overall compared with 66 percent in the United States).

Teachers' goals can influence how they teach material and the activities they emphasize. In 1995, eighth grade mathematics teachers in the United States were more likely than those in Japan or Germany to prioritize the goal of developing correct answers to problems. German and Japanese teachers made students' understanding of mathematical concepts the priority.

Science class practices in 1999 tended to emphasize student-directed investigations. Higher proportions of science students in the United States than in TIMSS-R countries overall said that they "pretty often or almost always" explained the reasoning behind an idea, worked on science projects, conducted experiments or investigations, and worked from worksheets or textbooks. On average, U.S. students watched teachers show them how to work through a science problem less often than did students in other countries (NCES 2000a). The frequency of other specific learning practices, including explaining observations, representing or analyzing relationships with tables and graphs, and working on problems with no obvious method of solution, did not significantly differ between the United States and the international average (NCES 2000a).

Although U.S. mathematics (and science) teachers report that they are familiar with and are implementing recent content and pedagogical reforms, detailed observation and analysis of mathematics classroom practice in 1995 suggest otherwise. TIMSS data indicate that Japanese eighth grade mathematics teachers were more likely than their U.S. counterparts to be practicing many of the reforms recommended by national organizations like NCTM (NCES 1997b). Teachers who report reforming their methods may be referring to aspects of practice that have little demonstrated effect on students' thinking. In one study, more than two-thirds of reform-oriented teachers identified either real-world applications or students working in groups as examples of reform practices, and only 19 percent identified activities involving problem solving or mathematical thinking (Hiebert and Stigler 2000).

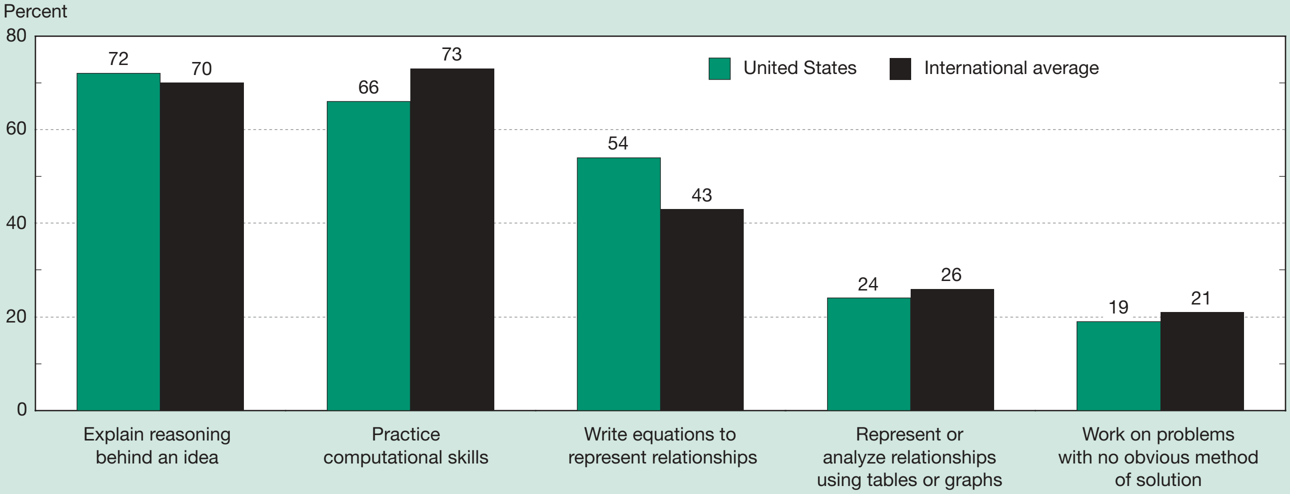
Teacher Quality

Although defining and measuring teacher quality remains difficult, a growing consensus is developing about some of the characteristics of high-quality teachers. Research studies have found that teachers more effectively teach and improve student achievement if they themselves have strong academic skills (Ehrenberg and Brewer 1994, Ferguson and Ladd 1996, and Hanushek 1996), appropriate formal training in the field in which they teach (Ingersoll 1999), and several years of teaching experience (Murnane and Phillips 1981). The body of expert opinions on teacher effectiveness has been summarized in several studies and commission reports (Darling-Hammond 2000; NCTAF 1996 and 1997; and Wayne and Younger 2003).

Some indicators of quality, such as education, certification, and subject-matter knowledge, are components in the

Figure 1-14

Students whose teachers asked them to do various activities in most or every mathematics lesson: 1999



SOURCE: I. V. S. Mullis et al., 2001, *Mathematics Benchmarking Report: TIMSS 1999–Eighth Grade. Achievement for U.S. States and Districts in an International Context* (Chestnut Hill, MA: International Association for the Evaluation of Educational Achievement and Boston College, International Study Center, 2001).

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definition of *highly qualified* teachers in the NCLB Act. For example, starting in fall 2002, the act requires all newly hired elementary and secondary school teachers in Title I schools to hold at least a bachelor's degree and to have full state certification or licensure. In addition, new elementary school teachers must pass tests in subject-matter knowledge and teaching skills in mathematics, reading, writing, and other areas of the basic elementary school curriculum. New middle and high school teachers either must pass a rigorous state test in each academic subject they teach or have the equivalent of an undergraduate major, graduate degree, or advanced certification in their fields (No Child Left Behind Act 2001).

This section discusses these and related indicators of teacher quality, which include the academic abilities of those entering the teaching force, teachers' education and preparation prior to teaching, the match or mismatch between teachers' training and the subject areas they are assigned to teach, and teachers' levels of experience.

Academic Abilities of Teachers

Some evidence suggests that college graduates who enter the teaching profession tend to have lesser academic skills. Using data from the National Longitudinal Study of 1972 high school seniors, Vance and Schlechty (1982) found college graduates with low Scholastic Aptitude Test (SAT) scores more likely than those with high SAT scores to enter and remain in the teaching force. Ballou (1996), using data from the Surveys of Recent College Graduates, found that the less selective the college, the more likely that its students prepared for and entered the teaching profession.

Data from the 2001 Baccalaureate and Beyond Longitudinal Study yielded similar findings. Recent college graduates who taught or prepared to teach were underrepresented among graduates with college entrance examination scores in the top quartile (table 1-1). Results for first-time mathematics and science teachers reflected the overall pattern: 18

Table 1-1

1999–2000 college graduates according to college entrance examination score quartile, by elementary/secondary teaching status: 2001

(Percent distribution)

		Score, quartile		
Teaching status	Total	Bottom	Middle half	Top
Did not teach				
Did not prepare	100	24	49	27
Prepared	100	39	50	11
Taught	100	36	48	16
Math in first teaching job	100	34	49	18
Public school	100	34	51	15
Science in first teaching job	100	27	56	17
Public school	100	26	61	13

NOTES: Substitute teachers and teacher's aides were not considered to have taught. "Prepared" refers to completing a teacher education program or a student teaching assignment but not yet having earned a teaching certificate. Percents may not sum to 100 because of rounding. SAT combined score is derived as either the sum of SAT verbal and mathematics scores or the ACT composite score converted to an estimated SAT combined score.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Baccalaureate and Beyond Longitudinal Study, 2001.

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and 17 percent, respectively, of those who reported teaching science or mathematics in their first job scored in the top quartile on the college entrance examination test compared with 27 percent of those who had neither prepared to teach nor taught. Among those who taught mathematics or science in public schools, an even lower percentage scored in the top quartile: 15 percent for mathematics teachers and 13 percent for science teachers.

However, not all studies have yielded similar results. For example, Latham, Gitomer, and Ziomek (1999) examined the SAT scores of candidates who took and passed the Educational Testing Service (ETS) Praxis II tests between 1994 and 1997 and found that those seeking to teach mathematics and science had higher average mathematics and verbal SAT scores than other college graduates.[12] Using data from the National Education Longitudinal Study of 1988 (NELS:88), Cardina and Roden (1998) found that female high school graduates intending to major in education in college exhibited a range of academic abilities measured by mathematics, science, and reading proficiency levels comparable to that of females intending to major in other fields such as psychology, business, or the health professions.

All of these studies relied heavily on standardized test scores as the sole indicator of the academic competence of teachers or prospective teachers, a major limitation that neglected other traits that may well be associated with teaching effectiveness. For the most part, they also used only a small subsample of teachers (i.e., recent college graduates who entered teaching) or samples of potential teacher candidates (i.e., those seeking to become teachers or intending to major in education), rather than a representative sample of all teachers in the workforce.

Teacher Education and Certification

Although teachers' knowledge of subject matter and pedagogical methods does not guarantee high-quality teaching, this knowledge is a necessary prerequisite. Therefore, teachers' educational attainment and certification status traditionally have been used to gauge teachers' preservice preparation and qualifications (NCES 1999). The conventional route to teaching begins with completion of a bachelor's degree. Although this was once considered adequate preparation for teaching, teachers today often are expected to hold advanced degrees. Indeed, many states and districts, as part of their efforts to raise academic standards, require teachers to attain a master's degree or its equivalent (Hirsch, Koppich, and Knapp 2001).

In academic year 1999, virtually all public school teachers had at least a bachelor's degree and nearly half also had an advanced degree: 42 percent held a master's degree and 5 percent had earned a degree higher than a master's degree, including an educational specialist or professional diploma or a doctoral or first professional degree (table 1-2).[13,14] The degree attainment of mathematics and science teachers was similar to the pattern for all teachers.[15] In comparison, only 26 percent of the overall population age 25 and over had completed 4 or more years of college in 2000 (NCES 2002b).

As of academic year 1999, 47 percent of public secondary school teachers had majored in an academic subject, 39 percent had majored in subject-area education (such as mathematics education), 7 percent had majored in general education, and 7 percent had majored in another education field for their undergraduate or graduate degree (figure 1-15). Thus, although almost all teachers have at least a bachelor's degree, many have an education degree rather than an academic degree.

Having an education degree does not mean that a teacher lacks subject-matter knowledge. As shown in figure 1-15, most secondary teachers with education degrees had subject-matter education majors such as mathematics education or science education. In recent years, many states have upgraded teacher education by requiring subject-area education majors to complete substantial coursework in an academic discipline. At many teacher-training institutions, a degree in mathematics education currently requires as much coursework in the mathematics department as does a mathematics degree (Ingersoll 2002).

Certification is another important measure of teacher qualifications. Teacher certification, or licensure by the state in which one teaches, includes requirements for formal education (usually a bachelor's degree with requirements

Table 1-2
Public school teachers according to highest degree earned: Academic year 1999
(Percent distribution)

Highest degree earned	All teachers	Mathematics and science teachers
All degrees	100	100
Less than bachelor's	1	0
Bachelor's	52	50
Master's	42	44
Higher than master's	5	5

NOTES: Percents may not sum to 100 because of rounding. Academic year refers to the school year beginning in fall 1999.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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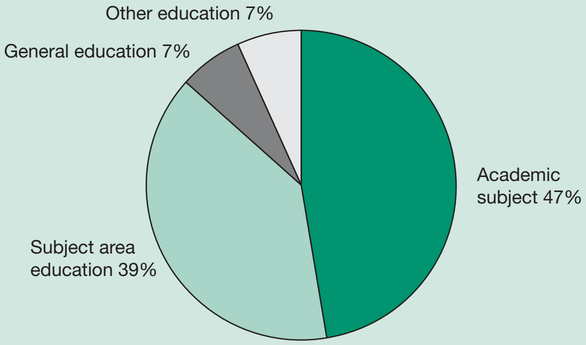
[12] Praxis II tests are designed to measure teachers' content and pedagogical knowledge of the subjects they will teach. States often use them to grant initial teaching licenses.

[13] The level of teachers' educational attainment remained fairly stable during the past decade. In academic year 1987, 99 percent of public school teachers held at least a bachelor's degree, including 47 percent who had a master's degree or higher (Choy et al. 1993).

[14] Data for the analysis on teachers' education, certification, match between preparation and assignment, and experience are based on a nationally representative sample of teachers who participated in the 1999–2000 NCES Schools and Staffing Survey (SASS).

[15] Mathematics and science teachers are identified by their main assignment field, i.e., the subject area they taught most often.

Figure 1-15
Distribution of secondary public school teachers, by undergraduate or graduate major: 1999–2000



NOTES: Subject area education is the study of methods for teaching an academic field, such as mathematics education. General education includes preelementary and early childhood education, elementary education, and secondary education. Examples of other education fields are special education, curriculum and instruction, and educational administration. Secondary school teachers include those who taught at least one of grades 7–12 and whose main assignment field was not prekindergarten, kindergarten, general elementary, or special education; those who taught special education to seventh and eighth grades only but were designated secondary teachers by the school; and those who taught “ungraded” students and were designated secondary teachers by the school. Teachers with more than one major (graduate or undergraduate) or degree were counted only once. Majors/degrees were counted in the following order: academic field, subject area education, other education, and general education.

SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), *The Condition of Education 2002,* NCES 2002-025, Indicator 32 (Washington, DC: U.S. Department of Education, 2002).

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for special courses related to teaching), clinical experience (student teaching), and often, some type of formal testing (Mitchell et al. 2001). Types of certification and requirements for each type vary considerably across states. Although most states have increased their standards since the 1980s, more than 30 states still allow hiring of teachers who have not met state licensing standards. This practice actually has increased in some states because the demand for teachers has grown due to increased enrollment and reduced class size (Darling-Hammond 2000 and Jepsen and Rivkin 2002). Some states allow the hiring of teachers who do not have a license, and others fill short-term vacancies by issuing emergency, temporary, or provisional licenses to candidates who may or may not have met various requirements. More than 40 states have developed various alternative certification procedures allowing individuals interested in teaching (i.e., former Peace Corps volunteers, liberal arts college graduates, and military retirees) to become teachers without first completing a formal teacher education program (Feistritzer 1998 and Shen 1997).

In academic year 1999, a vast majority of public school teachers (87 percent overall and 81 percent of mathematics and science teachers) had advanced or regular certification in their main teaching assignment field (appendix table 1-12). Some teachers (8 percent overall and 9 percent of mathematics and science teachers) held other types of certification, including probationary, provisional or alternative, temporary, or emergency certifications. About 6 percent of teachers in public schools held no certification in their main assignment field. These teachers might be certified in another field that may or may not be related to their main teaching field. Mathematics and science teachers more often lacked certification in their main assignment field, and this phenomenon occurred more frequently in academic year 1999 than in academic year 1993. In academic year 1993, about 7 percent of mathematics and science teachers in public schools lacked certification (Henke et al. 1997) compared with 10 percent in academic year 1999.

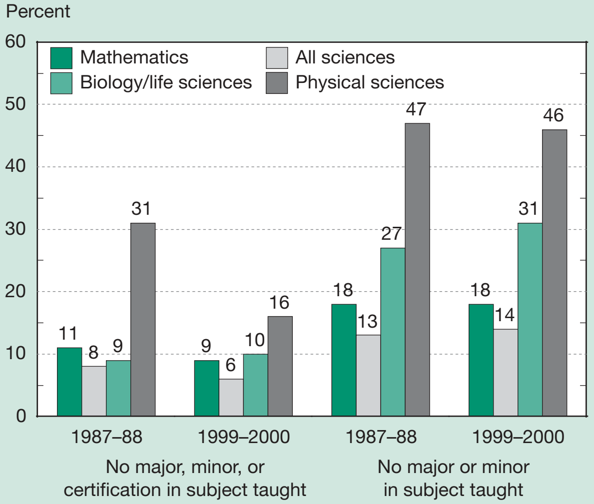
Match Between Teacher Preparation and Assignment

A growing body of research suggests that teachers’ subject-matter knowledge is one of the most important elements of teacher quality and that students, particularly in the higher grades, benefit most from teachers with strong subject-matter background (Goldhaber and Brewer 1997 and 2000; Monk and King 1994; and Rowan, Chiang, and Miller 1997). However, studies show that teaching “out of field” (teachers teaching subjects outside their areas of subject-matter training and certification) is not an uncommon phenomenon (Bobbitt and McMillen 1995 and Seastrom et al. 2002). In academic year 1999, 9 percent of public high school students enrolled in mathematics classes, 10 percent of students enrolled in biology/life science classes, and 16 percent of students enrolled in physical science classes received instruction from teachers who had neither certification nor a major or minor in the subject they taught (figure 1-16).

If the definition of a “qualified teacher” is limited to those who hold at least a college minor in the subject taught, the amount of out-of-field teaching substantially increases: 18 percent of public high school students in mathematics classes received instruction from teachers without at least a minor in mathematics, statistics, mathematics education, or a related field, such as engineering and physics. About 31 percent of students in biology/life science classes and 46 percent of students in physical science classes received instruction from teachers who did not have a major or minor in these subjects (figure 1-16). These percentages changed little between academic years 1987 and 1999. (See sidebar, “International Comparisons of Teacher Preparation in Eighth Grade Mathematics and Science,” and figure 1-17.)

The amount of out-of-field teaching varies in different types of schools. In general, students in high-poverty schools more often received instruction from out-of-field teachers than students enrolled in more affluent schools (Ingersoll 1999 and 2002). The following discussion examines the mismatch between those teaching mathematics and science and their academic backgrounds in those fields and how this mismatch varies by poverty level and minority concentration.

Figure 1-16
Public high school students taught by mathematics and science teachers without various qualifications, by subject field: 1987–88 and 1999–2000



NOTES: Biology/life and physical sciences are included in all sciences. Fields of study considered a mathematics major or minor include mathematics education, mathematics, statistics, physics, and engineering. Fields of study considered a science major or minor include science education, biology/life sciences, chemistry, geology/earth sciences, physics, other natural sciences, and engineering. Fields of study considered a biology/life science major or minor include biology/life sciences, and those considered a physical science major or minor included chemistry, geology/earth sciences, physics, and engineering.

SOURCE: M. M. Seastrom et al., *Qualifications of the Public School Teacher Workforce: Prevalence of Out-of-Field Teaching 1987–88 to 1999–2000,* NCES 2002-603 (Washington, DC: U.S. Department of Education, 2002).

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Mathematics

The amount of out-of-field teaching depends on how strictly one defines a match between teacher preparation and teaching assignment. In academic year 1999, 40 percent of public school students in high grades (hereafter referred to as *high school* students) studied mathematics with a teacher who majored in mathematics or statistics (figure 1-18). Another 32 percent studied with a teacher who majored in mathematics education. Broadening the definition to include teachers who minored in mathematics or statistics raised the match by 5 percentage points. Adding those who majored or minored in a natural science, computer science, or engineering increased the total by another 5 percentage points, for a total match of approximately 82 percent. In other words, about 18 percent of public high school students studied mathematics with a teacher who did not major or minor in mathematics or a related field. Middle grade students were less likely than their peers in high grades to be taught mathematics by a teacher with a degree in mathematics or statistics and more likely to study mathematics with a teacher without any formal training in mathematics or a related field (figure 1-18).

Biology/Life Sciences

Sixty-three percent of public high school students received instruction in biology or life sciences from a teacher with a major in that subject in academic year 1999. An additional 6 percent studied with a teacher who minored in biology/life sciences, another 6 percent studied with a teacher who majored or minored in another natural science (i.e., chemistry, geology/earth sciences, or physics), and 9 percent studied with a teacher with an undergraduate or graduate degree in science education (figure 1-18). Thus, about 15 percent of public high school students received instruction in biology/life sciences from a teacher without a degree in biology, life sciences, or a related field. Middle grade students studied with a teacher who taught out of field even more often.

Physical Sciences

The match between teaching assignment and teacher preparation in physical sciences follows a similar pattern to that for biological sciences, although, at 41 percent, high school students less often received instruction in physical sciences from a teacher who majored in a physical science (including chemistry, geology/earth sciences, physics, or other natural sciences), or who majored in engineering, and more often received instruction from a teacher who minored in physical sciences or engineering (14 percent). (Figure 1-18.) It also was not

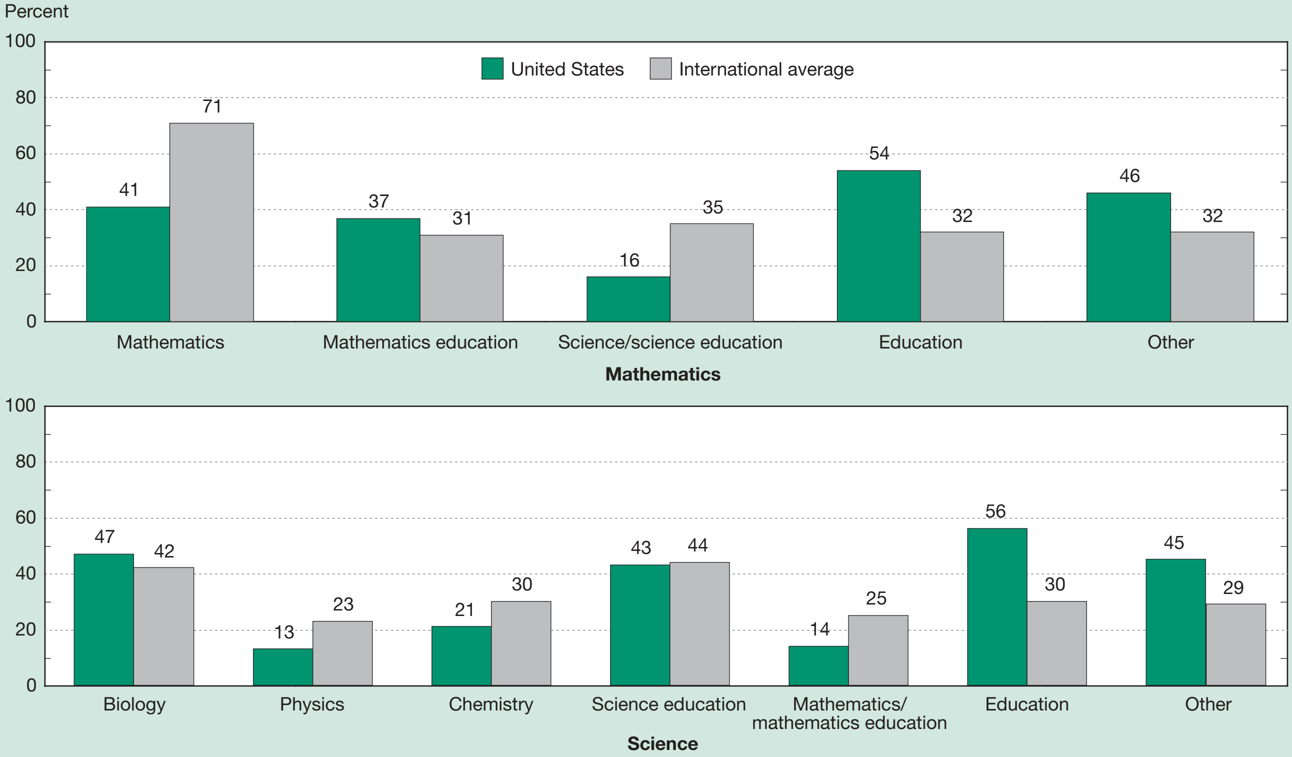
International Comparisons of Teacher Preparation in Eighth Grade Mathematics and Science

In the Third International Mathematics and Science Study-Repeat (TIMSS-R) conducted in 1999 (4 years after the original TIMSS), mathematics and science teachers of eighth graders were asked about their main areas of study (i.e., their majors or the international equivalent) at the bachelor's and master's degree levels. In 1999, 41 percent of eighth grade students in the United States received instruction from a mathematics teacher who specialized in mathematics (i.e., majored in it at the undergraduate or graduate level or studied mathematics for certification), considerably lower than the international average of 71 percent (figure 1-17). In science, U.S. eighth graders were about as likely as their international peers to receive instruction from a teacher with a bachelor's or master's degree major in biology, chemistry, or science education. However, they were less likely than their international peers to receive instruction from a teacher who majored in physics (13 percent of U.S. students compared with 23 percent of international students) and more likely to receive science instruction from a teacher who majored in education (56 percent of U.S. students compared with 30 percent of international students).

SOURCE: NCES 2001b, Indicator 43.

Figure 1-17

Eighth graders taught mathematics and science by teachers who reported various main areas of study for bachelor's and master's degrees: 1999



NOTES: More than one category could be selected when teachers chose their major/main area of study. International average includes the following countries: Australia, Belgium-Flemish, Bulgaria, Canada, Chile, Chinese Taipei, Cyprus, Czech Republic, England, Finland, Hong Kong, Hungary, Indonesia, Islamic Republic of Iran, Israel, Italy, Japan, Jordan, Latvia, Lithuania, Malaysia, Moldova, Morocco, Netherlands, New Zealand, Philippines, Republic of Macedonia, Romania, Russian Federation, Singapore, Slovak Republic, Slovenia, South Africa, South Korea, Thailand, Tunisia, Turkey, and United States.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2001,* NCES 2001-072, Indicator 43 (Washington, DC: U.S. Department of Education, 2001).

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uncommon for high school physical science students to receive instruction from teachers who majored or minored in biology/life sciences (16 percent) or who majored in science education (13 percent). Sixteen percent of high school students received instruction in physical sciences from an out-of-field teacher (i.e., no major or minor in a physical science, engineering, or a related field). As with mathematics and biology/life sciences, middle grade students more often received instruction in physical sciences from an out-of-field teacher.

Variations Across Schools

Students in high-poverty public high schools were as likely as students in low-poverty schools to receive mathematics instruction from teachers who majored in mathematics or statistics, or to receive instruction in biology/life sciences from teachers with a major in biology/life sciences (appendix table 1-13).[16] However, students in high-poverty public high schools received instruction in physical sciences from a teacher who majored in physical sciences less often. About 31 percent of students in high-poverty public high schools studied physical sciences with a teacher who majored in that field compared with approximately 42 percent of students in low-poverty schools. In addition, students in high-poverty and high-minority schools less often received mathematics or science instruction from a teacher who majored in mathematics or science education.

No statistically significant differences existed in the percentage of students who had an out-of-field mathematics, biology/life science, or physical science teacher by either school poverty level or minority concentration (appendix table 1-13).

Teacher Experience

Research examining the effects of teacher experience on student learning has found a relationship between teachers' effectiveness and their years of experience (Murnane and Phillips 1981; and Rowan, Correnti, and Miller 2002).

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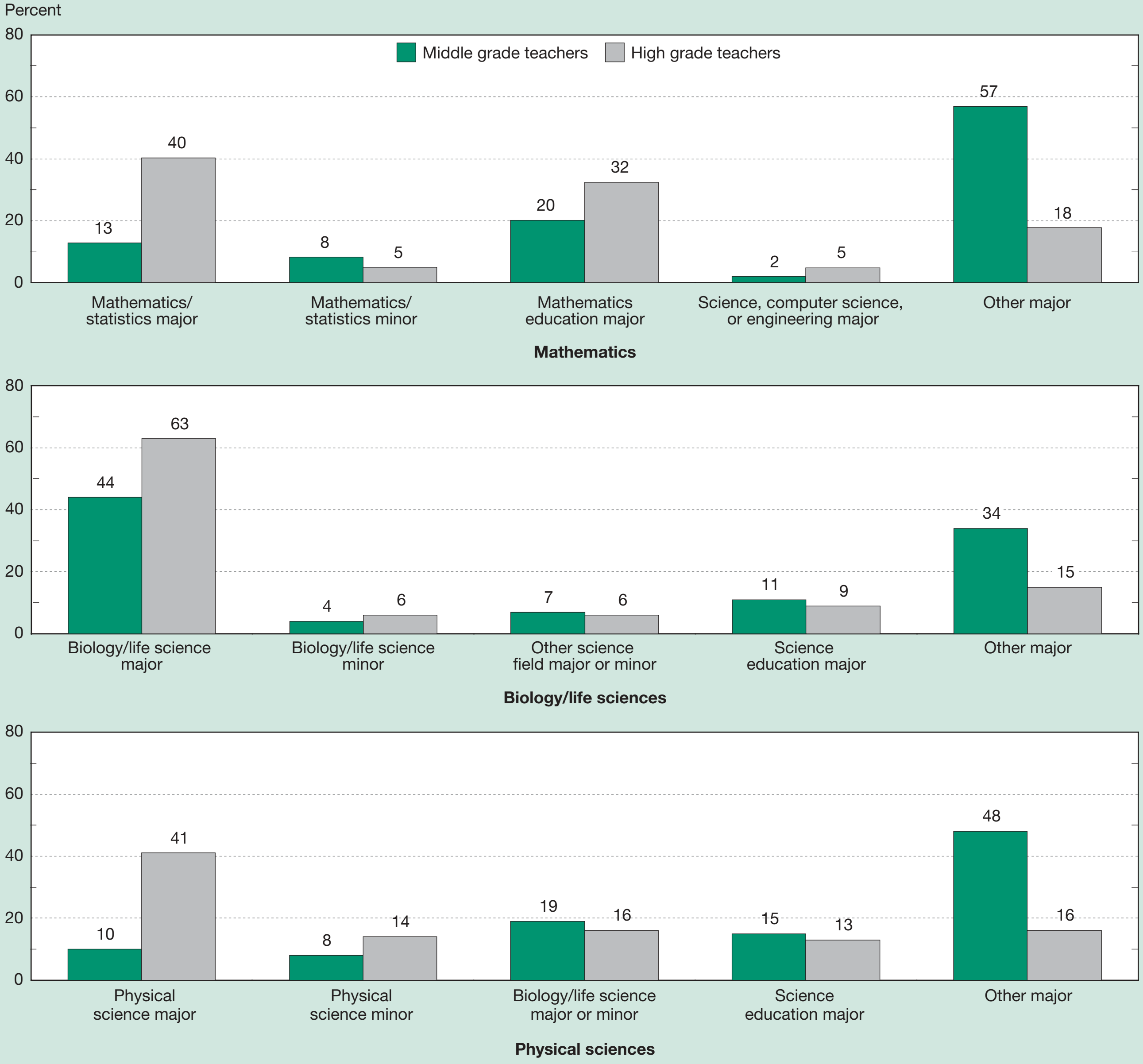
[16] High-poverty high schools are those schools in which 50 percent or more of students are approved to receive free or reduced-price lunches. Low-poverty high schools are those with 10 percent or less of students approved to receive free or reduced-price lunches.

Figure 1-18
Public school students whose mathematics and science teachers majored or minored in various subject fields, by teacher grade level: 1999–2000



NOTES: Middle grade teachers include teachers who taught students in grades 5–9 and did not teach any students in grades 10–12; teachers who taught in grades 5–9 who identified themselves as elementary or special education teachers were excluded. High grade teachers include all teachers who taught any of grades 10–12 and teachers who taught grade 9 and no other grades. Physical sciences include chemistry, geology/earth sciences, physics, other natural sciences, and engineering, except biology/life sciences.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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Many studies have established that inexperienced teachers typically are less effective than more senior teachers, but the measurable benefits of experience appear to level off after 5 years (Rosenholtz and Simpson 1990).

In academic year 1999, new teachers (i.e., those with 3 years of experience or fewer) made up 17 and 19 percent, respectively, of mathematics and science teachers in public middle and high schools compared with 16 percent of teachers in all other areas (figure 1-19).

Among public high schools, high-poverty schools and high-minority schools both had a higher proportion of new science teachers than low-poverty schools and low-minority schools[17] (figure 1-20). High-poverty schools had a lower share of the most experienced mathematics and science

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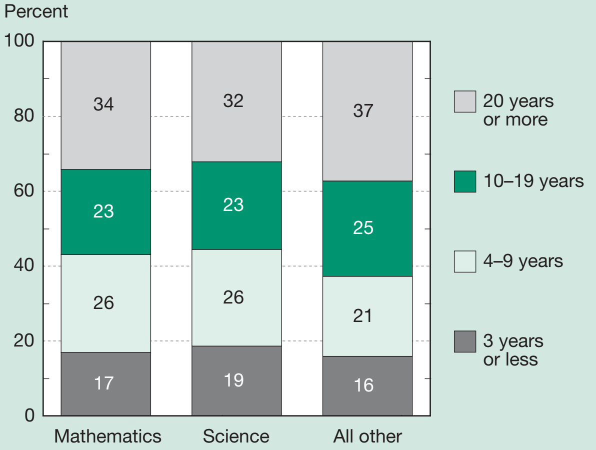
[17] High-minority high schools are those with minority enrollment of 45 percent or more, and low-minority high schools are those with enrollment of 5 percent or less.

Figure 1-19

Public middle and high school teachers with various years of teaching experience, by subject field: 1999–2000



NOTE: Percents may not sum to 100 because of rounding.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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teachers (those with 20 or more years of experience) compared with low-poverty schools; high-minority schools also had a lower share of the most experienced science teachers compared with low-minority schools.

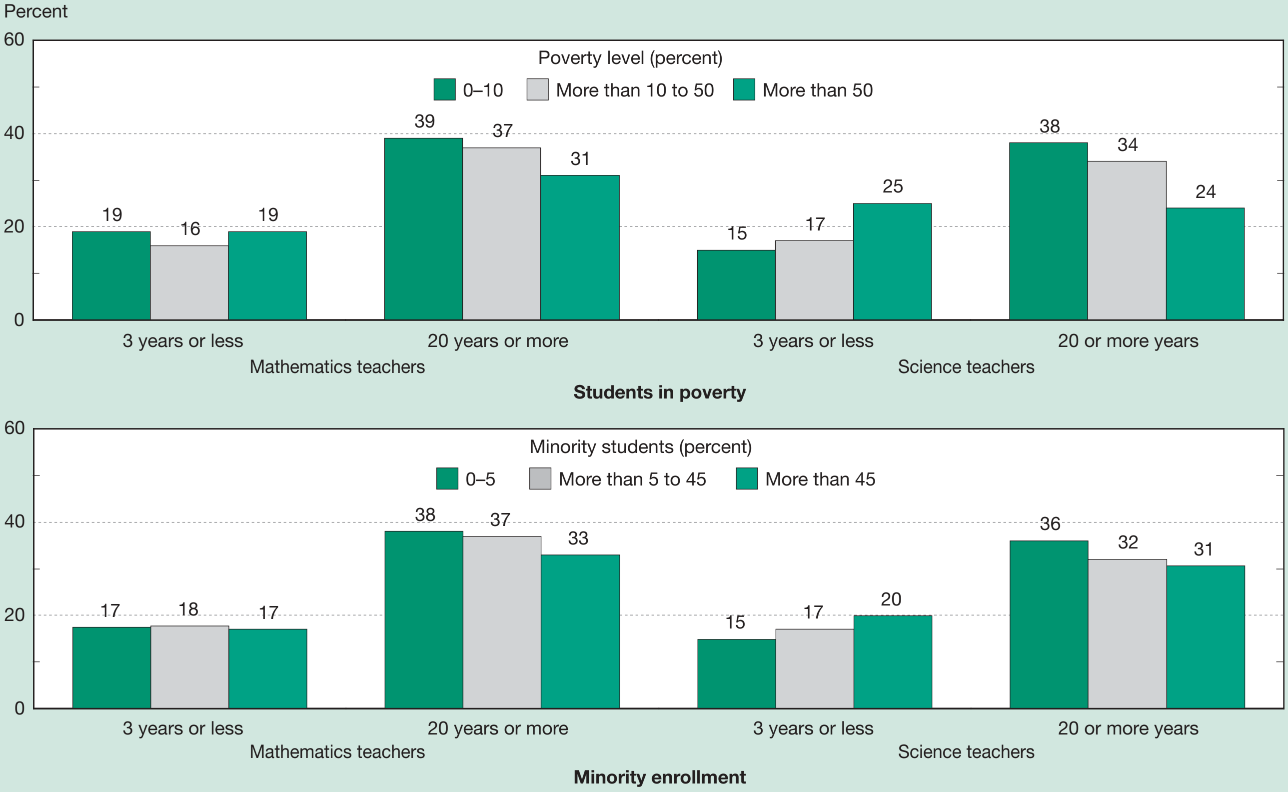
Teacher Induction, Professional Development, and Working Conditions

Recent school reform initiatives have drawn increased attention to the role of professional development and working conditions in enhancing teacher quality and guaranteeing an adequate supply of well-qualified teachers (NCTAF 1996, 1997, and 2003; National Education Goals Panel 1995; National Foundation for the Improvement of Education 1996; and No Child Left Behind Act 2001). The need for professional development has become more urgent as the nation's schools prepare for increased teacher retirements over the next decade (NCTAF 2003).

Research shows that teachers cite working conditions as among the top reasons for leaving their teaching jobs (NCTAF 2003). Inadequate support from administrators, student discipline problems, little faculty input into school decision making, inadequate facilities and supplies, and low salaries

Figure 1-20

Experience of public high school mathematics and science teachers, by poverty level and minority enrollment in schools: 1999–2000



NOTE: Students in poverty are those who are approved to receive free or reduced-priced lunches.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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all contribute to teacher turnover (Ingersoll 2001, NCTAF 2003, and NCES 1997a). This section examines teachers' professional development and working conditions, based on the responses of a nationally representative sample of teachers in the 1999–2000 Schools and Staffing Survey (SASS), and has a special focus on public middle and high school mathematics and science teachers.

New Teacher Induction

Induction programs typically have two goals: to improve the skills of beginning teachers and to reduce attrition. The National Commission on Teaching and America's Future (1996) contended that school districts usually assign new teachers to classes (often those with the most difficult students), and leave them to cope on their own. These initial experiences can contribute to high turnover rates among new teachers (NCES 1997a, and NCTAF 2003). To ease new teachers' entry into the profession, many school districts increasingly use formal induction and mentoring programs to help them adjust to their new responsibilities (AFT 2001).

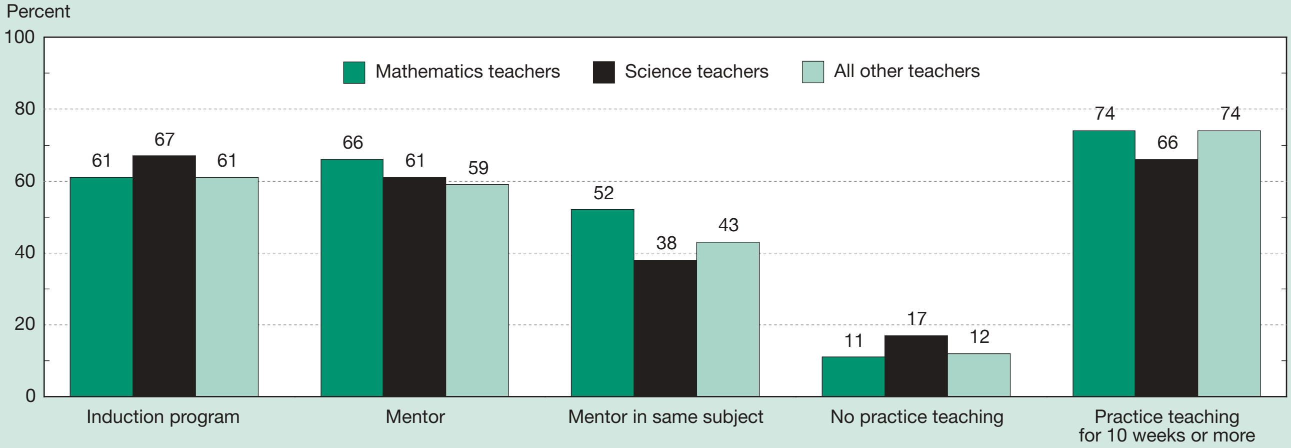
Among public middle and high school mathematics teachers who entered the profession between 1995 and 1999 (hereafter referred to as *recently hired teachers* or *new teachers*), 61 percent participated in an induction program in their first year of teaching (figure 1-21). A similar proportion (66 percent) reported that they worked with a master or mentor teacher, although fewer (52 percent) reported working with another mathematics teacher as their mentor. Recently hired science teachers had similar participation rates in induction programs and mentorship activities, although even fewer new science teachers (38 percent) reported being mentored by someone who teaches in the same subject area.

Induction participation rates did not significantly differ between new mathematics teachers in high- and low-poverty public high schools (61 versus 56 percent), but were significantly lower for new science teachers in high-poverty schools compared with their counterparts in low-poverty schools (51 versus 70 percent) (appendix table 1-14). Participation in mentoring activities did not significantly differ for new mathematics and science teachers in high- and low-poverty schools.

In addition to induction and mentoring, new teachers also can benefit from practice teaching before they enter the classroom. In academic year 1999, a majority of new mathematics and science teachers in public middle and high schools (89 and 83 percent, respectively) performed practice teaching before entering teaching (figure 1-21). For most of them (74 and 66 percent, respectively), practice teaching lasted for 10 or more weeks (figure 1-21). Participation in practice teaching was significantly related to schools' poverty level and minority enrollment. In public high schools, new mathematics and science teachers in high-poverty schools were less likely than their counterparts in low-poverty schools to have performed practice teaching for 10 weeks or more; in fact, they were more likely to have not performed practice teaching at all (appendix table 1-14). Similar gaps in practice teaching experience also existed between high- and low-minority schools.

A vast majority of new mathematics and science teachers in public middle and high schools reported they felt well prepared to teach mathematics or science in their first year of teaching (figure 1-22). At least two-thirds felt well prepared to perform various teaching activities such as planning lessons, assessing students, and using a variety of teaching methods in their classes. At least half felt well prepared in

Figure 1-21
Public middle and high school teachers who entered profession between 1995–96 and 1999–2000 and participated in induction and mentoring activities in first year and those with either no or 10 weeks or more of practice teaching, by subject field: 1999–2000



SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000. See appendix table 1-14.

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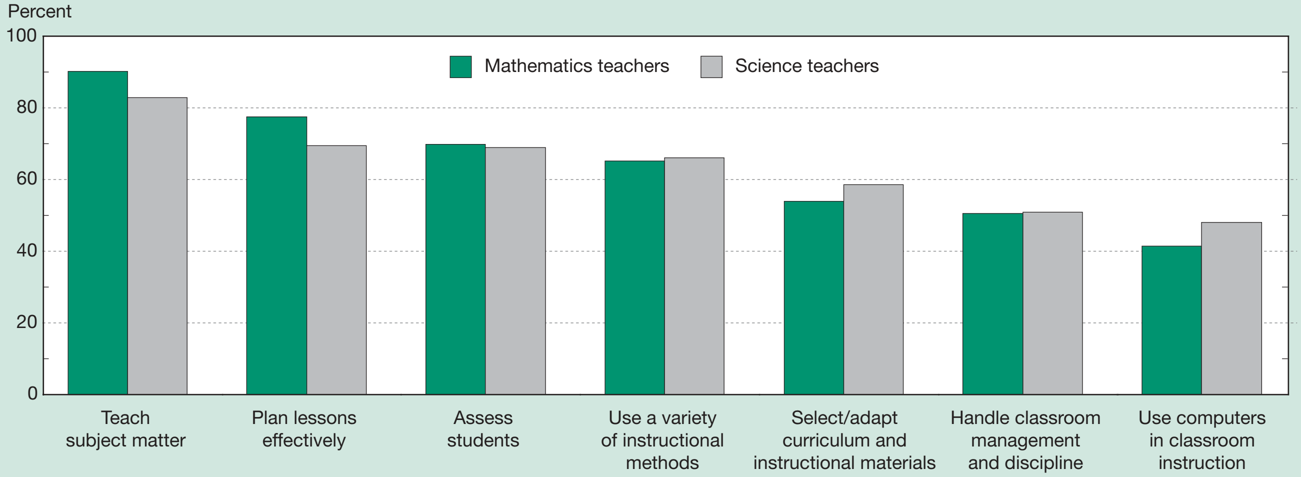
Figure 1-22
Public middle and high school mathematics and science teachers who entered profession between 1995–96 and 1999–2000 and reported feeling well prepared in various aspects of teaching in first year: 1999–2000



SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000. See appendix table 1-15.

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selecting or adapting curriculum and instructional materials and in handling a range of classroom management and discipline situations. About 41 percent of new mathematics teachers and 48 percent of new science teachers felt well prepared to use computers for classroom instruction.

A positive relationship existed between participation in induction and mentoring programs and new teachers' feelings of preparedness. For example, new mathematics teachers who participated in an induction program more often felt well prepared to use computers for classroom instruction, and those who worked with a mentor teacher more often felt well prepared to use a variety of instructional methods in the classroom (appendix table 1-15). Participation in induction programs and mentoring activities had an even more positive relationship to feelings of preparedness among new science teachers than among new mathematics teachers. New science teachers who had induction or mentoring experiences more often reported feeling well prepared in planning lessons effectively, assessing students, selecting or adapting curriculum and instructional materials, and using a variety of teaching methods compared with their counterparts who did not have such experiences.

Teacher Professional Development

The following analysis reviews the content of professional development programs in which public middle and high school mathematics and science teachers participated during the 12 months before the SASS survey took place in academic year 1999.

Teacher Professional Development Program Content

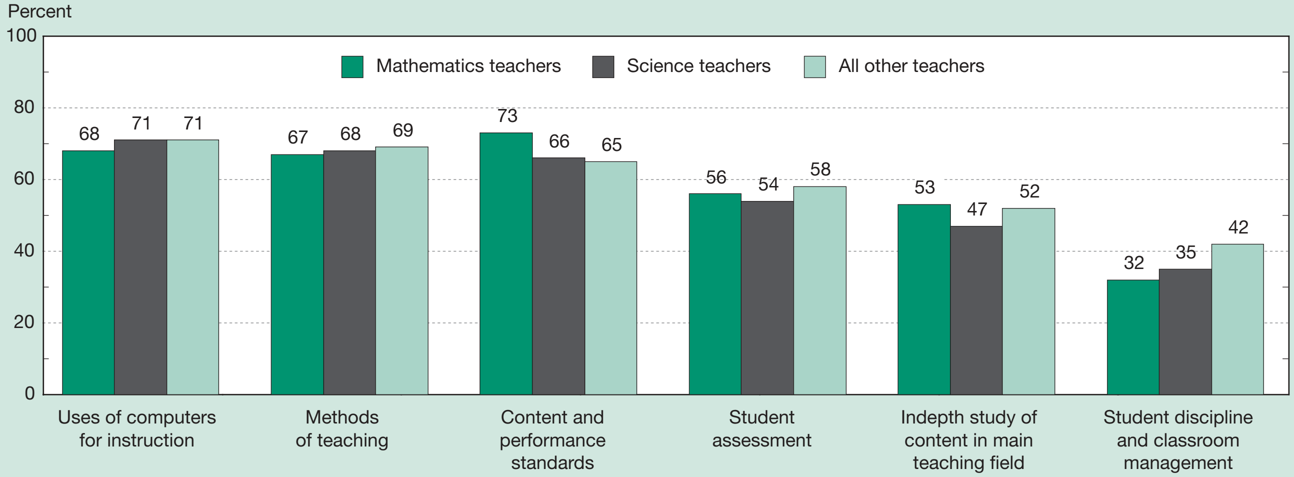
Mathematics and science teachers exhibited a pattern of participation in professional development programs similar to the pattern exhibited by all other teachers. Teachers reported the use of computers for instruction, methods of teaching, and content and performance standards as the three top subjects for professional development in academic year 1999. Between 66 and 73 percent of public middle and high school mathematics and science teachers reported participating in professional development programs on one of these three topics (figure 1-23). Slightly more than half of mathematics and science teachers (56 and 54 percent, respectively) reported participating in programs on student assessment. Participation in indepth study of content in a teacher's main field ranked comparatively lower, reported by 53 percent of mathematics teachers and 47 percent of science teachers. Teachers were least likely to have participated in programs on student discipline and classroom management.

Both mathematics and science teachers rated use of technology for instruction as one of their top interests for future professional development (figure 1-24). They also gave high ratings to study in their main subject field. Methods of teaching, teaching students with special needs, and student assessment received the lowest ratings.

Teacher Professional Development Program Duration

One of the most important concerns about teacher professional development is the duration of training. Richardson (1990) notes that providing adequate time for professional development programs is crucial to allow teachers to learn and absorb the information supplied during their training. A recent study that used a nationally representative sample of

Figure 1-23
Public middle and high school teachers who participated in professional development programs that focused on various topics in past 12 months, by subject field: 1999–2000



SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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Figure 1-24
Public middle and high school mathematics and science teachers who rated various topics as first priority for additional professional development: 1999–2000

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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mathematics and science teachers to identify characteristics of effective professional development supported this statement (Garet et al. 2001). Researchers generally agree that short-term professional development activities are not as conducive to meaningful change in teaching performance as more intensive activities (Little 1993).

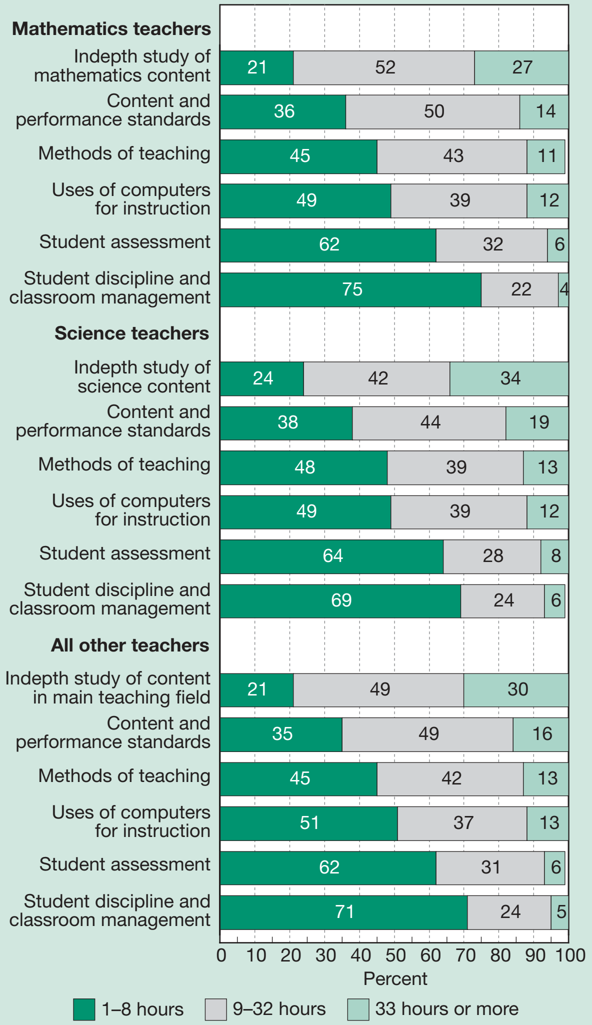
Although the majority of mathematics and science teachers (68 and 71 percent, respectively) reported participation in professional development programs on the use of computers for instruction (figure 1-23), only about half of those participants reported attending such programs for more than 8 hours, or the equivalent of 1 or more days (figure 1-25). Mathematics and science teachers were most likely to spend more than 1 day of professional training on the indepth study of their main subject field or on content and performance standards. Between 42 and 52 percent of mathematics and science participants reported spending more than 1 day of training on these two topics and an additional 14 to 34 percent reported participating for about a week or more. The topics on which teachers spent the least amount of time in training were student assessment and discipline and classroom management.

Perceived Usefulness of Professional Development

Available national surveys provide information about the prevalence of professional development, topic coverage, and duration, but reveal little about the structure and quality of these programs (Mayer, Mullens, and Moore 2000). Using the 1993–94 SASS, Choy and Chen (1998) found that most teachers had positive views about the impact of their professional development programs. For example, 85 percent of teachers who participated in professional development programs thought these programs provided them with new information, 65 percent agreed that these programs made them change their teaching practices, and 62 percent agreed that the programs motivated them to seek further information or training. Parsad, Lewis, and Farris (2001) also found that most teachers (at least 89 percent) who participated in professional development programs in various areas believed that these programs somewhat improved their teaching. Teachers who participated in longer programs reported this more often than those who participated only in shorter programs.

In academic year 1999, mathematics and science teachers who participated in professional development programs on various topics for more than 8 hours generally found them useful. In public middle and high schools, approximately three-fourths of teachers who participated in longer programs covering indepth study of their main subject field or the use of computers for instruction found these programs useful or very useful (appendix table 1-16). Approximately two-thirds of participants found programs on content and performance standards, student assessment, student discipline and classroom management, and methods of teaching useful. Teachers' perceptions of the usefulness of various professional development programs were related to their duration: teachers who participated in training for 8 hours or more were more likely than those who participated for from 1 to 8 hours to report that the training was useful or very useful.

Figure 1-25
Public middle and high school teachers who participated in professional development programs on various topics, by time spent on topic and subject field: 1999–2000



NOTE: Percents may not sum to 100 because of rounding.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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Teacher Salaries and Working Conditions

Although good working conditions can help attract and retain teachers, salary also matters. In an effort to attract and retain high-quality teachers, many states and school districts are attempting to raise teacher salaries and improve working conditions (NCTAF 2003). The following analysis examines trends in teacher salaries over recent decades, compares salaries of U.S. teachers to those of their counterparts in other nations, and looks at conditions in which teachers work.

Trends in Teacher Salaries

Average salaries (in constant 2001 dollars) of all public K–12 teachers decreased between 1970 and 1980 by about $700 annually (Nelson, Drown, and Gould 2002) (figure 1-26). Teacher salaries rose in the 1980s and continued to grow, albeit slowly, during the 1990s. In academic year 2000, the average salary for all public K–12 teachers was $43,250. After adjusting for inflation, this was about $1,000 more than the average salary of teachers in academic year 1990.

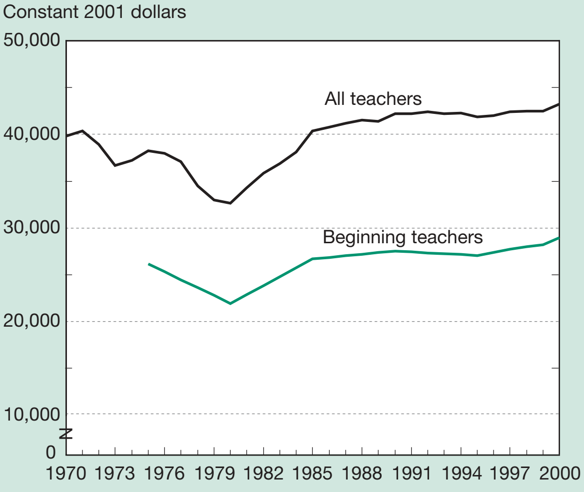
The overall trend of salaries for beginning teachers resembled the trend for all teachers. However, during recent years, beginning teacher salaries have risen faster than the salaries of all teachers, increasing more than 4 percent in academic years 1999 and 2000 compared with 3.3 to 3.4 percent for all teachers (Nelson, Drown, and Gould 2002). However, beginning teachers receive substantially lower salaries than the average salary for new college graduates in other occupations. In academic year 2000, the average starting salary offer to college graduates in other occupations was $42,712, whereas the average salary for beginning teachers was just under $29,000 (Nelson, Drown, and Gould 2002). Teacher salaries typically are 9-month based.

International Comparisons of Teacher Salaries

Compared with teachers in many other countries, U.S. teachers are paid relatively well. In 2000, the annual statutory salaries of lower and upper secondary teachers with 15 years of experience in the United States were about $40,072 and $40,181, respectively, compared with respective averages of $31,221 and $33,582 for teachers in OECD countries (figure 1-27).[18]

Figure 1-26

Salary trends for public K–12 and beginning teachers: Academic years 1970–2000



NOTE: Salary data for beginning teachers before 1975 were not available.

SOURCE: F. H. Nelson, R. Drown, and J. C. Gould, *Survey & Analysis of Teacher Salary Trends 2001* (Washington, DC: American Federation of Teachers, 2002).

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Nevertheless, teacher pay scales in the United States tend to be lower than those in a number of other countries. For example, the annual statutory salary of U.S. lower secondary teachers with 15 years of experience ($40,072) lagged behind those of Switzerland (U.S. dollars $54,763), South Korea (U.S. dollars $43,800), and Japan (U.S. dollars $42,820). Gaps were particularly wide at the upper secondary (high school) level because some countries require higher educational qualifications and thus pay teachers significantly more at this level. For example, in 2000, the statutory salaries for upper secondary teachers with 15 years of experience exceeded $42,000 in Germany, the Netherlands, Belgium, South Korea, and Japan, and exceeded $65,000 in Switzerland (OECD 2002). The comparable salary for the United States was about $40,000.

Comparing statutory salaries relative to per capita gross domestic product (GDP) is another way to assess the relative value of teacher salaries across countries. A high salary relative to per capita GDP suggests that a country invests more of its financial resources in its teachers. Relative to per capita GDP, teacher salaries rank lowest in the Czech Republic, Hungary, and Norway, and highest in South Korea, Switzerland, and Spain (figure 1-27). The United States had a below-average ratio of teacher salaries relative to per capita GDP (1.12 compared with 1.35 for lower secondary teachers, and 1.12 compared with 1.45 for upper secondary teachers). These data indicate that the United States spent a below-average share of its wealth on teacher salaries.

Variation in Average Salaries of U.S. Mathematics and Science Teachers

The 1999–2000 SASS data indicate that the base salaries of public middle and high school mathematics and science teachers averaged between $39,000 and $40,000 in academic year 1999, a range similar to that for all other teachers (figure 1-28). Their average earnings, which included additional school-year compensation (e.g., from coaching, sponsoring a student activity, or teaching evening classes), summer school salaries, and any nonschool earnings, totaled between $42,000 and $45,000 for mathematics and science teachers, not significantly different from the average earnings of between $43,000 and $45,000 for all other teachers.

Mathematics and science teachers in high-poverty public high schools tended to earn less than their counterparts in low-poverty public high schools, but the pattern differed in schools with high- and low-minority enrollment (figure 1-29). Mathematics teachers in high-minority schools earned more than their counterparts in low-minority schools ($46,000 compared with $42,000), and science teachers in

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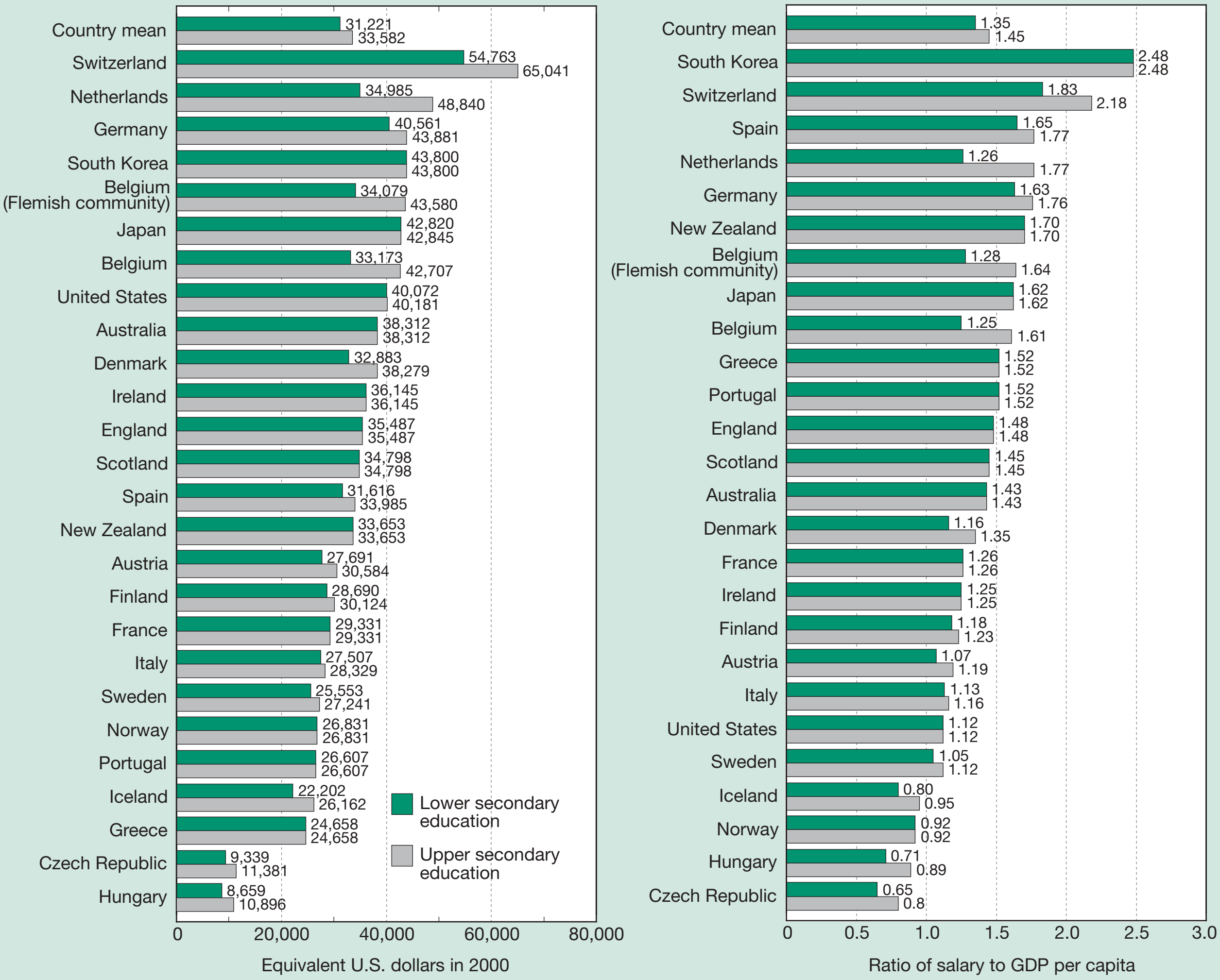
[18] Statutory salaries refer to official pay scales and are different from actual salaries, which are also influenced by other factors such as the age structure of the teaching force or the prevalence of part-time work (OECD 2002). Salaries are expressed in equivalent U.S. dollars converted using OECD purchasing power parities (see discussion in chapter 4).

Figure 1-27
Annual statutory salary of public school teachers with 15 years experience and ratio of statutory salaries to GDP per capita, by level of schooling and OECD country: 2000



GDP gross domestic product
OECD Organisation for Economic Co-operation and Development

NOTES: Salaries refer to scheduled annual salary of full-time teacher with minimum training necessary to be fully qualified. OECD countries are Australia, Austria, Belgium, Belgium (Flemish community), Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, South Korea, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States. Turkey and Mexico were omitted from this figure because of missing data.

SOURCE: OECD, *Education at a Glance: OECD Indicators 2002* (Paris, 2002).

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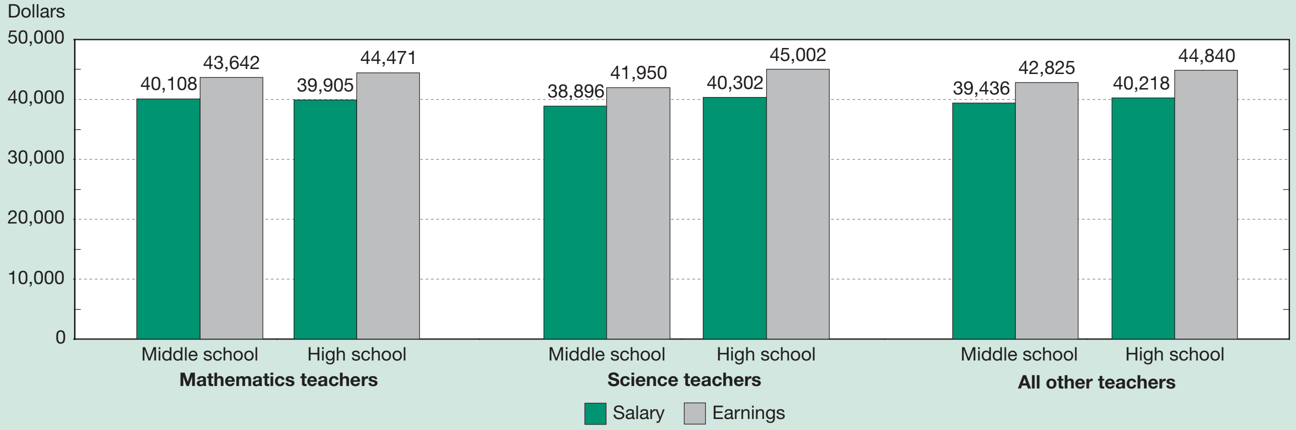
high-minority schools earned about the same as their counterparts in low-minority schools ($45,000 compared with $43,000). These differences may partially reflect different experience levels.

Mathematics and science teachers in high-poverty public high schools were less likely than their counterparts in low-poverty schools to feel satisfied with their salaries (figure 1-29). Although teachers in high-minority schools earned more than (mathematics teachers) or as much as (science teachers) their counterparts in low-minority schools, they were less satisfied with their salaries. Differences in cost of living and working conditions may help explain this finding.

Other Aspects of Working Conditions

Other aspects of teachers' working conditions can affect teacher recruitment and retention (Ingersoll 2001, NCES 1997a, and NCTAF 2003). The 1999–2000 SASS data indicate that, in many respects, teachers found their working environments to be supportive. A majority of public high school teachers agreed that their principal made staff members aware of expectations (86 percent) and enforced school rules (79 percent), they received support and encouragement from their school administration (77 percent), their school district made necessary materials available (75 percent), and staff members worked together cooperatively (73 percent) (figure 1-30). However, teachers in high-poverty and high-

Figure 1-28
Average base salary and total earnings of public school teachers, by subject field: 1999–2000



NOTE: Total earnings include base salary, additional school year compensation (e.g., from coaching, sponsoring a student activity, or teaching evening classes), summer school salaries, and any nonschool earnings.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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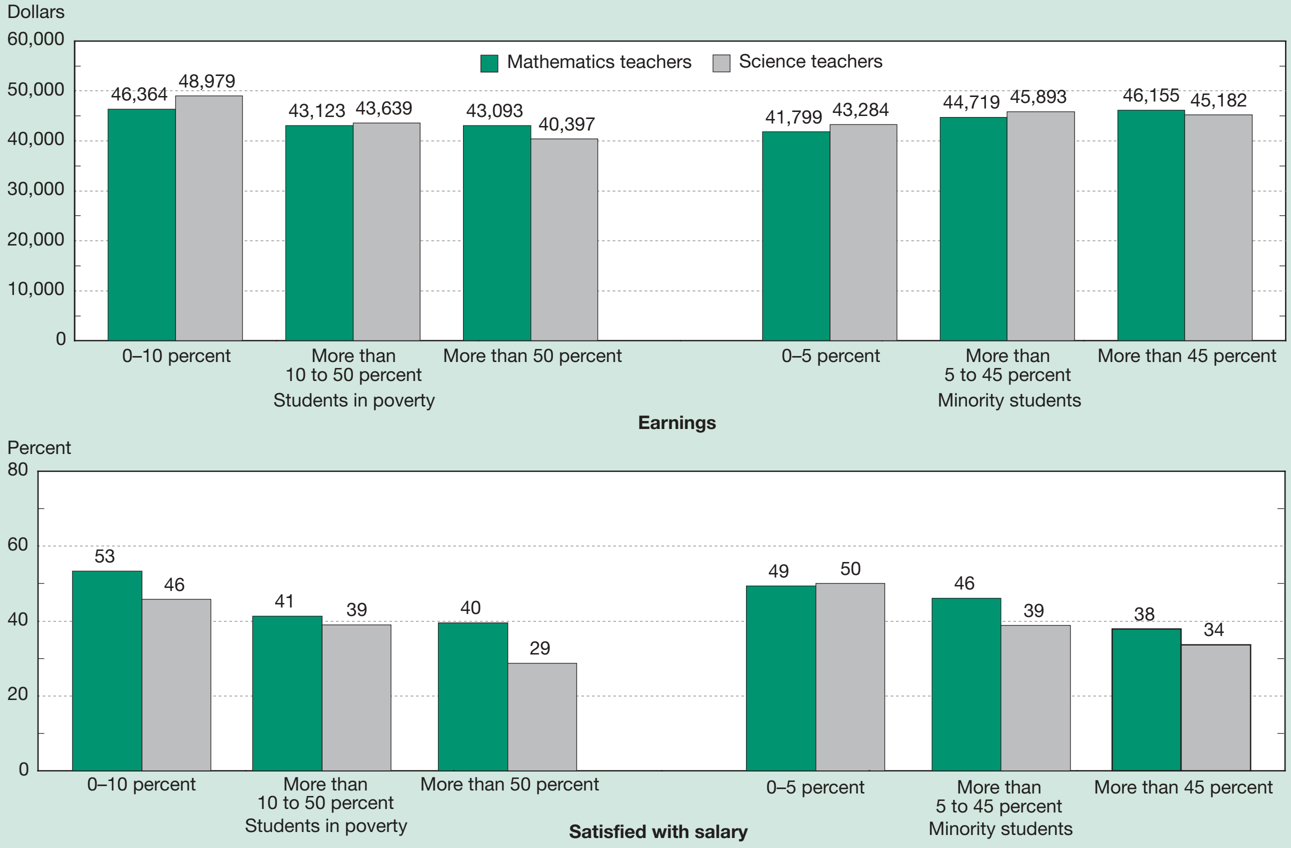
Figure 1-29
Total earnings of public high school mathematics and science teachers and percentage of teachers satisfied with salary, by poverty level and minority enrollment in school: 1999–2000



NOTE: Students in poverty are those who are approved for free or reduced-priced lunches.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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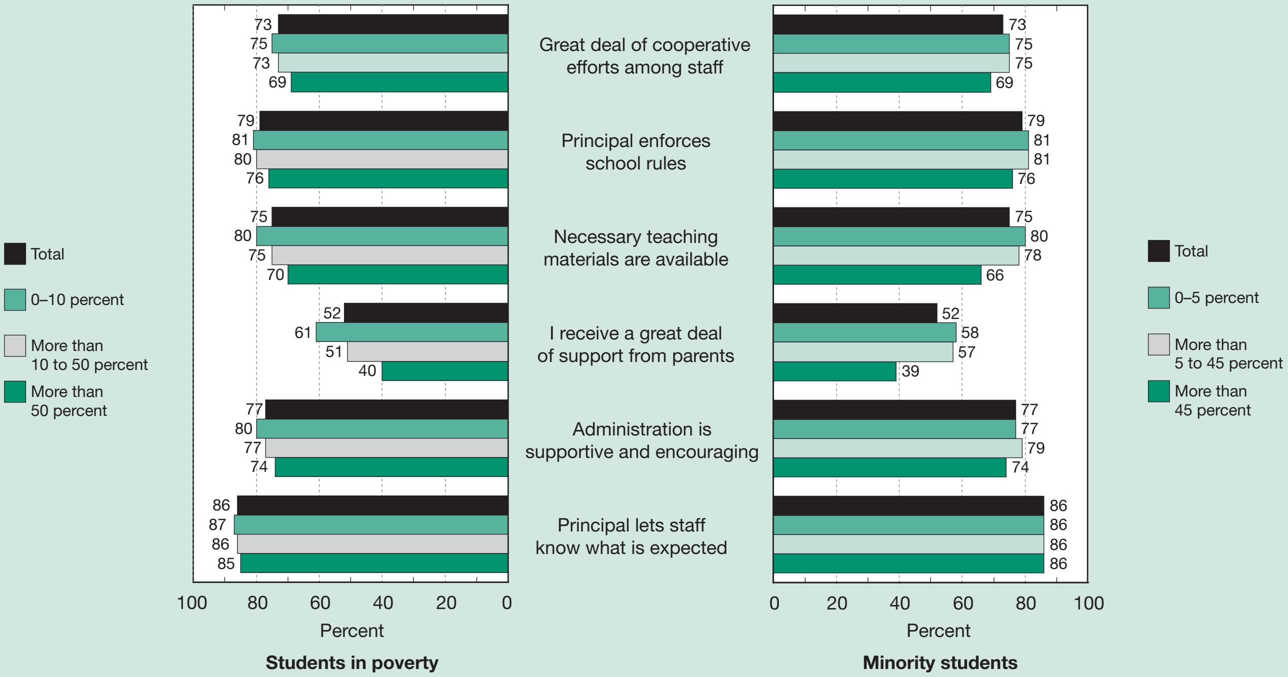
Figure 1-30
Public high school teachers who agreed or strongly agreed with various statements about support they received in school, by poverty level and minority enrollment in school: 1999–2000



NOTE: Students in poverty are those who are approved to receive free or reduced-priced lunches.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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minority schools had less favorable perceptions of their working conditions. They were less likely to report that they received a great deal of parent support, administrators provided support and enforced school rules, colleagues worked together cooperatively, and school districts made necessary teaching materials available (figure 1-30).

A majority of public high school teachers experienced some problems in their schools that they identified as moderate or serious. These problems included students coming to school unprepared to learn (72 percent), student apathy (69 percent), absenteeism (65 percent), tardiness (56 percent), disrespect for teachers (55 percent), and truancy (39 percent) (appendix table 1-17). These problems were more likely to be reported in high-poverty and high-minority schools.

Information Technology in Schools

As IT becomes more pervasive in U.S. society, unfamiliarity with IT will increasingly limit students' economic and educational opportunities. Data on student access to IT at home and at school provide indications of the degree to which Americans become acquainted with IT and the Internet during their school years, including the degree to which exposure varies with demographic characteristics.

Schools have sought to take advantage of IT to improve education. Much remains to be learned about how IT can be used to help students learn mathematics and science, and much experimentation is under way. The NCLB Act authorizes funds for states and districts to increase IT use, and it places particular emphasis on equalizing access for students in all schools.

This section describes data on student access to IT in school, ways in which schools currently use IT for instruction in mathematics and science, and teacher preparation for its use. It also looks at student access to IT at home.

IT Access at School

A vast majority of students now study in schools and classrooms with computers and at least some form of Internet access. Where differences in school access persist, they concern student-computer ratios, teacher preparation for using IT, and ways in which teachers use IT. These issues go beyond sheer access to encompass quality and effectiveness in IT use.

Access to computers and the Internet has increased rapidly during the past decade. Virtually all schools have Internet access in at least one location; in fact, most classrooms have access. By fall 2001, an estimated 99 percent of public schools and 87 percent of instructional rooms had Internet connections. (Instructional rooms include classrooms, computer and other labs, library/media centers, and any other rooms used for instructional purposes.) This represents a dramatic increase over 1994, when only 35 percent of public schools and 3 percent of instructional rooms had Internet connections (Kleiner and Farris 2002).

Schools with high concentrations of students eligible for the Free/Reduced-Price Lunch Program or with high minority enrollment tend to have somewhat less access. Classrooms in these schools were less likely to have computers and the number of students per Internet-accessible instructional computer was higher. In schools with 75 percent or more students eligible for the Free/Reduced-Price Lunch Program, the ratio of students to Internet-accessible computers reached 6.8:1, compared with 4.9:1 in schools with fewer than 35 percent eligible students. The figures for minority enrollments show a similar difference: a 6.4:1 ratio for schools with 50 percent or more minority enrollment versus a 4.7:1 ratio in schools with 5 percent or less minority enrollment. However, access in low-income and minority schools increased between 2000 and 2001. The proportion of instructional rooms with Internet access rose from 60 to 79 percent in schools with the highest concentration of poverty, and from 64 to 81 percent in schools with the highest minority enrollment (Kleiner and Farris 2002).

IT in Math and Science Instruction

As early as kindergarten, a majority of students have access to IT at school. According to the Early Childhood Longitudinal Study (ECLS), in spring 1999, most kindergartners used computers in the classroom at least weekly to learn mathematics (61 percent), and some used them to learn science (20 percent) (Rathburn and West 2003).

At the high school level, large majorities of public school teachers in all fields report using computers for instructional purposes (appendix table 1-18). Teachers who had used computers in classes during the previous 2 weeks were asked to select one of their classes and indicate how often they used computers for various purposes in that class. Teachers reported using computers for practicing skills, solving problems, learning course materials, and working collaboratively more often than they reported using them to produce multimedia projects or correspond with experts or others outside the school. In this respect, mathematics and science teachers did not differ greatly from their colleagues who teach other subjects.

NAEP data show substantially increased use of computers in mathematics and science classes between 1996 and 2000. In 2000, the percentage of mathematics teachers in grades 4, 8, and 12 who reported that their students had access to computers in their classrooms at all times increased at least 20 percentage points above the 1996 level. Computer use in fourth and eighth grade science classes also increased during this period. NAEP did not collect data on 12th grade science classes (NCES 2001c and 2003b).

In 2000, more than half of 12th grade science students used computers in each of the following ways: collecting data, analyzing data, downloading data and related information from the Internet, and using lab equipment that interfaces with computers. Almost half reported using the Internet to exchange information with other students or scientists about experiments (NCES 2003c). Educators are currently exploring a variety of new uses of IT (see sidebar “New IT Forms and Uses”).

High school mathematics and science teachers in schools with a high percentage of minority students who had used computers within the previous 2 weeks reported somewhat different use patterns than their counterparts in other high schools. These teachers were more likely to use computers to practice skills, solve problems, and teach course material in more class periods than teachers in schools with a lower percentage of minority students.

Teacher Preparation and Training in Using IT

Advocates for IT in schools stress that teachers need both targeted and meaningful professional development and timely, accessible, and ongoing technical support to help them use IT effectively in their teaching (Bray 1999, CEO Forum on Education and Technology 1999, and Hruskocy et al. 1997). The NCLB Act requires each local education agency receiving formula funds from state technology grants (Title II, Part D, Subpart 1) to allocate 25 percent of its funds for high-quality professional development toward integrating technology into instruction.

Recent large-scale studies indicate that teachers want more support in integrating IT into everyday classroom practice. In 1999, two-thirds of teachers listed inadequate teacher training as a barrier to effective IT use. However, new teachers (those with 3 or fewer years of teaching experience) were less likely to report that they were not at all prepared to use computers and the Internet for classroom instruction (10 percent) than teachers with 10 to 19 years of teaching experience (14 percent), or with 20 or more years (16 percent). In addition, teachers in this survey identified other barriers to using IT effectively as being as important as lack of training: lack of release time (82 percent), lack of scheduled time for students to use computers (80 percent), insufficient computers (78 percent), lack of good instructional software (71 percent), outdated computers with slow processors (66 percent), and difficulty accessing the Internet connection (58 percent) (NCES 2000c).

States are addressing the need for computer literacy among teachers. As of 2002, 26 states and the District of Columbia required IT training or coursework before initial teacher licensure. In seven states, teachers must demonstrate their technological skill in order to receive a license. Thirteen states offer various incentives, such as free laptop computers or continuing education credits, to encourage teachers to use IT in their classrooms. In 2002, 22 states offered incentives for principals and administrators to use IT in schools, up from 11 states in 2000 (Editorial Projects in Education 2002).

Teachers who participate in IT-oriented professional development activities appear likely to increase their use

New IT Forms and Uses

Some studies have found that although most teachers now use computers in their classrooms, they often use them for drill-and-practice exercises rather than for more sophisticated tasks and projects such as multimedia projects and teaching from Internet-based curricula (NCES 2000c). However, new forms of IT are introduced into the classroom each year. Distance education (in which time, location, or both separate the instructor and students) and online learning (also known as electronically delivered learning or *e-learning*) have begun to change the landscape of education, especially at the secondary level. Distance education courses are delivered to remote locations via synchronous (real time) or asynchronous means of instruction, and include written correspondence, text, graphics, audio- and videotape, CD-ROM, online learning, audio- and videoconferencing, interactive TV, and facsimile (Kaplan-Leiserson 2000).

E-learning covers a broad set of applications and processes, including Web-based learning, computer-based learning, virtual classrooms, virtual high schools, and digital collaboration.* It includes the delivery of content via the Internet, an intranet, audio- and videotape, satellite broadcast, interactive TV, or CD-ROM. Twelve states have established fully operational online or virtual high school programs for academic year 2001, and five other states have programs in development. Well-established virtual high schools in Florida and Utah have student enrollments in the thousands (Clark 2001). Twenty-five states allow for the creation of virtual, or cyber, charter schools, and 32 states have various e-learning initiatives underway, according to a new survey of state IT coordinators (Editorial Projects in Education 2002). These programs and policy changes make online education available to many more students. For example, e-learning may give students in small, rural, or less affluent high schools access to specialized courses such as AP courses. A recent report estimates that 40,000 to 50,000 K–12 students enrolled in an online course during academic year 2001 (Clark 2001). Currently, most of these students are high school students, but momentum to serve elementary and middle school pupils is building.

Popular innovative technologies that use a range of multimedia applications include digital white boards, videodisk, CD-ROM, and Web-based digital imaging. These technologies facilitate visualization and simulations in mathematics and science. In some cases, these technologies supplement other forms of instruction, whereas in others, they provide the basis for distance learning applications that do not include live instruction (Clark 2001; and Thompson, Ganzglass, and Simon 2001). Potential uses span the spectrum from embellishments within a traditional lecture to instruction that is completely Internet-based.

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* A virtual high school is a state-approved and/or regionally accredited school offering secondary courses through distance learning methods that include Internet-based delivery (Clark 2000).

of IT (Becker 1999, Fatemi 1999, and Wenglinsky 1998). Teachers who spent 9 or more hours per year on professional development in this area felt substantially better prepared to use computers and the Internet in class than those who had spent less time (NCES 2000c).

In addition to classroom applications, the Internet also provides teachers with the opportunity to expand their professional learning communities and to share curricula and instructional strategies with other teachers. Databases of curriculum materials and electronic discussion lists provide teachers with access to a broad range of resources and colleagues. Telementoring has become a popular way of providing effective coaching and training for teachers, especially in technology integration (Harris 1999). The Internet also facilitates schools' partnerships and communications with external organizations, parents, and the community. Industry partners sometimes help train teachers in how to use IT effectively or provide schools with financial resources and equipment (CEO Forum on Education and Technology 1999; Means 1998; and Rocap, Cassidy, and Connor 1998).

IT Access at Home

Because Internet access provides educational and social opportunities that can be increasingly important for school-aged children, it is important to look at access to this relatively recent technology outside the classroom. Approximately 77 percent of preteens (ages 10–13) and 86 percent of teens (ages 14–17) use the Internet when doing their schoolwork (figure 1-31).

Families with children more often have computers and Internet connections than do other households. According to a National Telecommunications and Information Administration report (NTIA 2002) based on September 2001 Current Population Survey (CPS) data, 70 percent of such families had computers compared with 59 percent of families with no children and 39 percent of nonfamily households.[19] Similar differences existed in Internet access, at 62 percent access for family households with children under the age of 18, 53 percent for family households with no children, and 35 percent for nonfamily households. Home access is much more unequally distributed than school access. Low-income (figure 1-32) and minority (NTIA 2002) children are much less likely than their peers to have Internet access at home.

Approximately one-third of children ages 10–17 in the lowest income category have home access to computers, but access in the highest income group is nearly universal. Overall computer use at school is much more equal, at 80 percent for children in the lowest income category and 89 percent for those in the highest income category. As a result, reliance on school for access is common for children in the lowest income category, where 52 percent use computers at school but not at home. However, it is rare in the highest income category,

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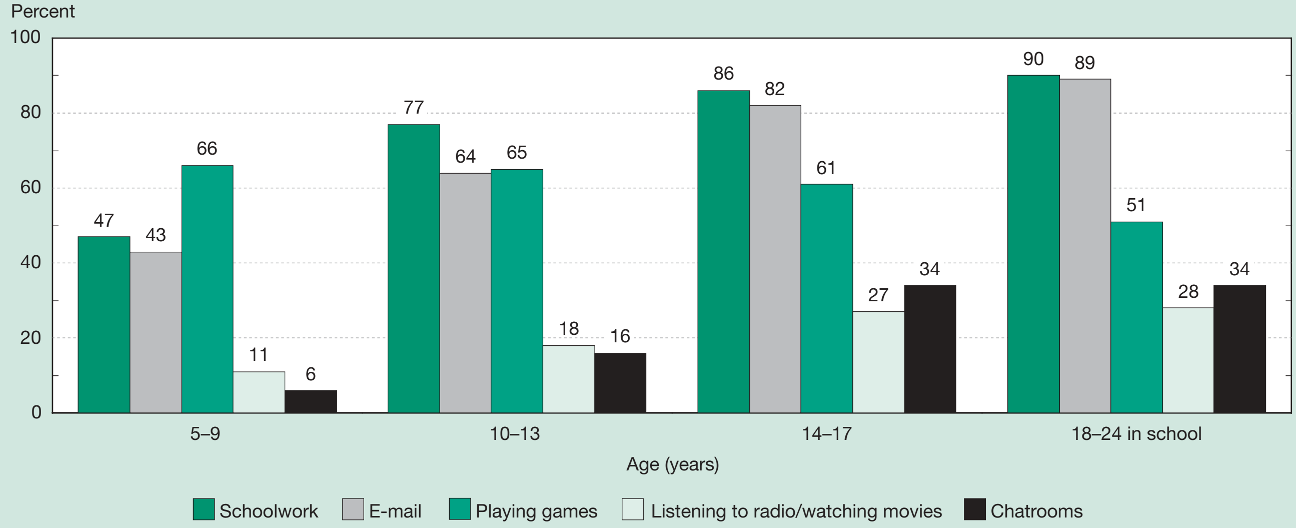
[19] Conducted by the U.S. Department of Commerce's Census Bureau, CPS provides a very reliable measure of computer and Internet access because it surveyed approximately 57,000 households containing more than 137,000 individuals in all 50 states and the District of Columbia.

Figure 1-31
Major uses of Internet among U.S. children and young adults, by selected age groups: 2001



SOURCES: U.S. Department of Commerce, National Telecommunications and Information Administration (NTIA) and Economics and Statistics Administration, using U.S. Bureau of the Census Current Population Survey Supplements, September 2001; and U.S. Department of Commerce, NTIA, *A Nation Online: How Americans Are Expanding Their Use of the Internet* (Washington, DC, 2002), http://www.esa.doc.gov/nationonline.cfm. Accessed 10 March 2003.

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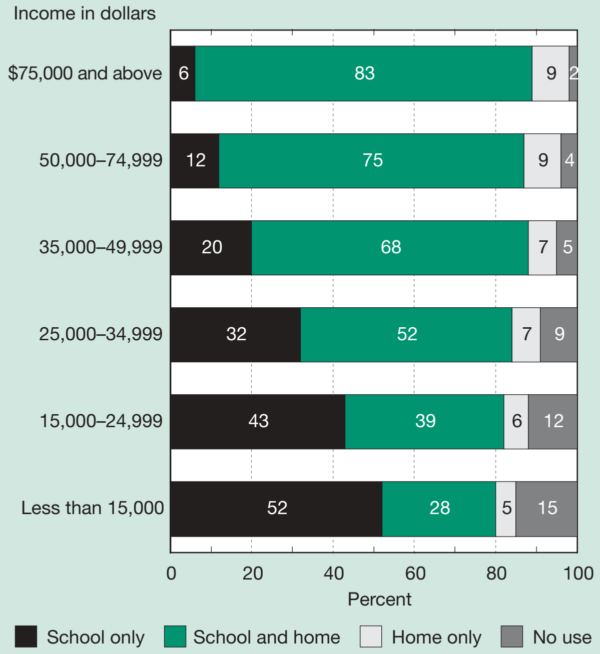
Figure 1-32
Computer use among 10–17-year-olds, by household income and location: 2001



NOTE: Percents may not sum to 100 because of rounding.

SOURCES: U.S. Department of Commerce, National Telecommunications and Information Administration (NTIA) and Economics and Statistics Administration, using U.S. Bureau of the Census Current Population Survey Supplements, September 2001; and U.S. Department of Commerce, NTIA, *A Nation Online: How Americans Are Expanding Their Use of the Internet* (Washington, DC, 2002), http://www.esa.doc.gov/nationonline.cfm. Accessed 10 March 2003.

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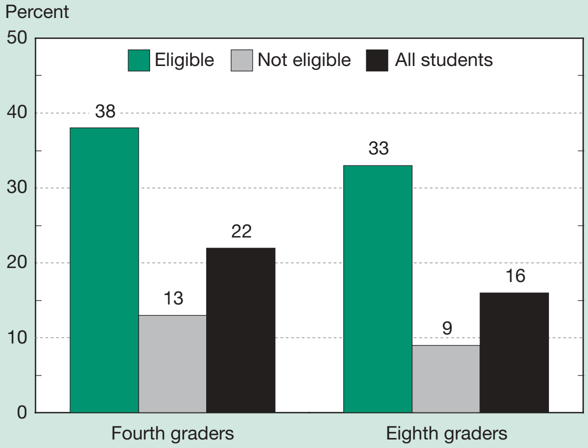
where the corresponding figure is 6 percent. Although schools do play a role in equalizing access, figure 1-32 also shows that the lower a family's income, the more likely it is that the children do not use computers at all.

NAEP data present similar findings about the relationship between income and home computer access. Overall, 78 percent of fourth graders and 84 percent of eighth graders reported having a computer available at home. Among students eligible for the Free/Reduced-Price Lunch Program, however, only 62 percent of fourth graders and 67 percent of eighth graders had computers at home (Editorial Projects in Education 2002) (figure 1-33).

Home access to the Internet is likewise strongly associated with family income. Figure 1-34 shows that 22 percent of children in the lowest income category use the Internet at home compared with 83 percent in the highest income category. A substantially larger disparity related to income exists in children's access to the Internet at school (35 percent of children in the lowest income households versus 63 percent of children from the highest income households) compared with the disparity for school computer access overall. As a result, a much greater difference exists in Internet use between children in the highest and lowest income groups (42 percentage points) than exists for computer use overall (13 percentage points) (figures 1-32 and 1-34). Thus, although schools have helped reduce the disparities associated with family income in children's overall access to computers, they appear to do much less to reduce income-related disparities in children's access to the Internet.

Racial and ethnic differences are also big. Black and Hispanic students lag far behind their white and Asian/Pacific

Figure 1-33
Fourth and eighth graders without computers at home, by eligibility for national free or reduced-price lunch programs: 2001



SOURCE: U.S. Department of Education, National Center for Education Statistics, NAEP Data Tool Online, 2000, http://nces.ed.gov/nationsreportcard/naepdata. Accessed 10 March 2003.

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Islander counterparts when it comes to home computer access, with 45 percent of black children and 39 percent of Hispanic children having access to a home computer compared with 79 percent of whites and 74 percent of Asian/Pacific Islanders (U.S. Bureau of the Census 2001).

At almost every income level, fewer households in rural areas own computers compared with those in urban or central city areas (NTIA 1999).

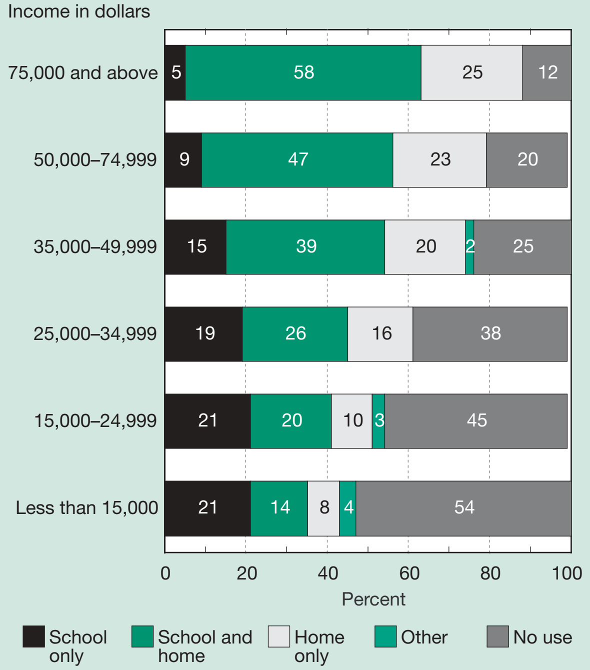
Transition to Higher Education

Adequate preparation of high school graduates for their transition to postsecondary education remains a concern. This section examines data on the college enrollment rates of high school graduates, compares postsecondary participation at the international level, and describes remedial coursetaking by U.S. college students.

Immediate Transition From High School to Postsecondary Education

The percentage of high school graduates who enrolled in postsecondary education immediately after graduation has increased over the past 3 decades, rising from 47 percent in 1973 to 62 percent in 2001 (figure 1-35 and appendix table 1-19) (NCES 2003a). The enrollment rate of any particular cohort or subgroup depends on several factors, including academic preparedness, access to financial resources (e.g., personal resources and financial aid), the value placed on postsecondary education relative to alternatives such as working, and the job market for high school graduates.

Figure 1-34
Internet use among 10–17-year-olds, by household income and location: 2001



NOTE: Percents may not sum to 100 because of rounding.

SOURCES: U.S. Department of Commerce, National Telecommunications and Information Administration (NTIA) and Economics and Statistics Administration, using U.S. Bureau of the Census Current Population Survey Supplements, September 2001; and U.S. Department of Commerce, NTIA, *A Nation Online: How Americans Are Expanding Their Use of the Internet* (Washington, DC, 2002), http://www.esa.doc.gov/nationonline.cfm. Accessed 10 March 2003.

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Sex, Race/Ethnicity, and Family Income

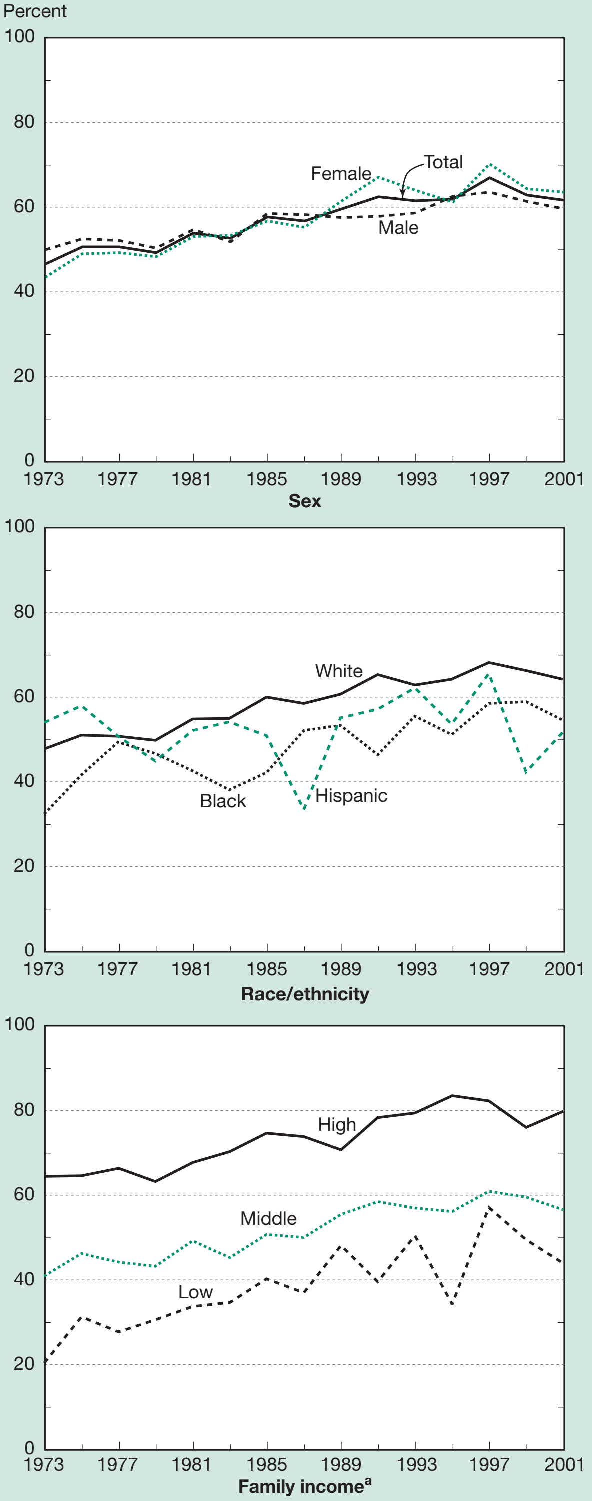
The immediate enrollment rate of high school graduates in 2- and 4-year colleges has increased more for females than males (figure 1-35 and appendix table 1-19). Between 1973 and 2001, the rate at which females enrolled in postsecondary institutions increased from 43 to 64 percent, whereas the rate for males increased from 50 to 60 percent.

The immediate enrollment rate for white high school graduates increased from 48 percent in 1973 to 64 percent in 2001 (figure 1-35 and appendix table 1-19). For black graduates, the immediate enrollment rate increased from 32 percent in 1973 to 55 percent in 2001. Although enrollment rates for blacks were generally lower than those for whites, the gap between the two groups has diminished since 1983. Among Hispanics, immediate enrollment rates remained relatively constant between 1973 and 2001; thus, the gap between Hispanic students and white students has increased.

The gap in immediate postsecondary enrollment rates between high school graduates from high- and low-income families persisted from 1973 to 2001 (figure 1-35 and appendix table 1-19). This gap reflects both differences in

Figure 1-35

High school graduates enrolled in college the October after completing high school, by sex, race/ethnicity, and family income: 1973–2001



^aLow income is the bottom 20 percent of all family incomes, high income is the top 20 percent, and middle income is the 60 percent in between.

NOTE: Includes students ages 16–24 completing high school in a given year.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2003*, Indicator 18, 2003. See appendix table 1-19.

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academic preparation and in financial resources available to pay college costs. It also reflects differences in the degree to which students take preparatory steps that lead to college enrollment such as aspiring to a bachelor's degree, taking a college admissions test, and applying for admission (NCES 2002a).

Access to Postsecondary Education: An International Comparison

Many countries have high rates of participation in education beyond secondary school. In 2000, OECD countries had an average 45 percent first-time entry rate into tertiary type A education programs leading to the equivalent of a bachelor's or higher degree, and an average 15 percent first-time entry rate into tertiary type B programs that focus on practical, technical, or occupational skills for direct entry into the workforce (figure 1-36).[20]

In 2000, U.S. students had entry rates of 43 and 14 percent for tertiary type A and B programs, respectively, which are comparable to the OECD country averages. Finland, New Zealand, Sweden, Iceland, Hungary, and Poland had entry rates for tertiary type A education of more than 60 percent, all significantly higher than the U.S. entry rate. At one time, the United States had a higher entry rate compared with most OECD countries (OECD 1992). However, many OECD countries have adopted policies to expand postsecondary education during recent years, leading to substantially increased participation. In OECD countries, the average 17-year-old in 2000 could be expected to go on to complete approximately 2.5 years of tertiary education, of which 2 years would be full-time study (OECD 2002).

Remedial Education in College

Despite the increasing number of graduates who enter college immediately after high school, many college freshmen apparently lack adequate preparation for higher education. Many postsecondary institutions (78 percent in 1995, for example) offer remedial courses to those needing assistance in doing college-level work (Lewis, Farris, and Greene 1996). Participation in college-level remedial education is widespread (Adelman, Daniel, and Berkovitz forthcoming). About 4 out of 10 students in the NELS:88 cohort who attended postsecondary institutions between 1992 and 2000 took at least one remedial course during their college years: 16 percent took one remedial course, 15 percent took two to

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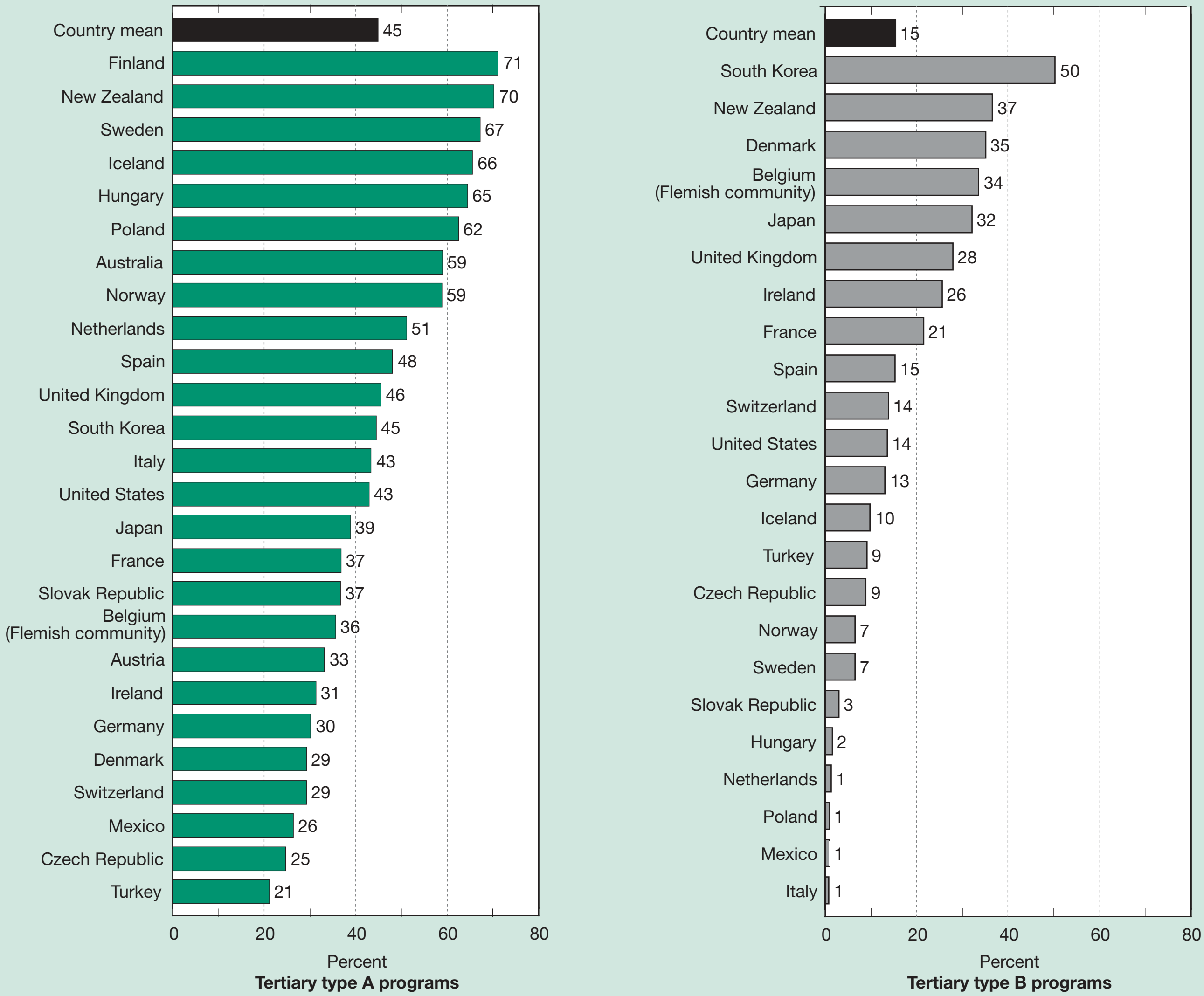
[20] Tertiary type A programs are theoretically based and are designed to provide sufficient qualifications for entry into advanced research programs or professions with high skill requirements. Tertiary type B programs focus on occupationally specific skills so that students can directly enter the labor market. Entry rates are obtained by dividing the number of first-time entrants of a specific age to each type of tertiary education by the total population in the corresponding age group and adding the entry rates for each single age group (OECD 2002). Entry rates do not refer to a specific population group. The U.S. entry rates reported by OECD cannot be directly compared with the immediate enrollment rates in figure 1-35 due to different definitions of postsecondary education and calculations of rates used in the OECD 2002 indicator report.

Figure 1-36
First-time entry rates to tertiary education, by program type and OECD country: 2000



OECD Organisation for Economic Co-operation and Development

NOTES: Tertiary type A programs are designed to provide sufficient qualifications for entry into advanced research programs and professions with high-skill requirements, such as medicine, dentistry, or architecture. Programs have a minimum cumulative duration of 3 years full-time equivalent, although they typically last 4 or more years. Tertiary type B programs focus on practical, technical, or occupational skills for direct entry into the labor market. They have a minimum duration of 2 years full-time equivalent at the tertiary level. OECD countries are Australia, Austria, Belgium, Belgium (Flemish community), Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, South Korea, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States. Because of missing data, Belgium, Canada, Greece, Luxembourg, and Portugal were not included in the figure for tertiary type A programs, and Australia, Austria, Belgium, Canada, Finland, Greece, Luxembourg, and Portugal were not included in the figure for tertiary type B programs.

SOURCE: OECD, *Education at a Glance: OECD Indicators 2002* (Paris, 2002).

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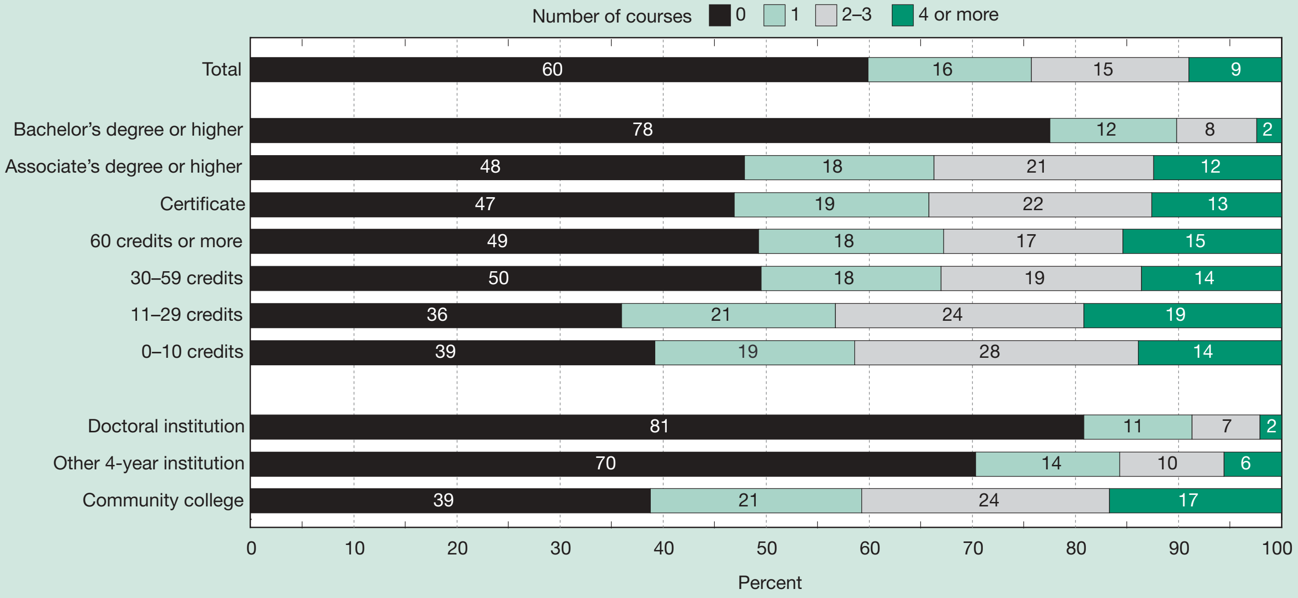
three remedial courses, and 9 percent took four or more such courses (figure 1-37).

Remedial coursetaking was related to students' postsecondary attainment level and the type of institution they first attended. Students who had earned at least a bachelor's degree by 2000 took fewer remedial courses than those who did not. Among those who did not earn any degree but who did accumulate undergraduate credits, at least half took a minimum of one remedial course. Remedial coursetaking occurred more often at community colleges than at 4-year institutions. About 62 percent of students who first attended community colleges took at least one remedial course compared with 20 percent of those who first attended doctoral degree-granting institutions and 30 percent of those who first attended other types of 4-year institutions (figure 1-37). These participation rates may reflect the remedial course offerings of different types of institutions, because 2-year community colleges typically serve as important providers

Figure 1-37
Students taking remedial courses after entering postsecondary education, by number of courses, attainment level, and type of first institution: 1992–2000



NOTES: Percents may not sum to 100 because of rounding. Included in total but not shown separately are students from other subbaccalaureate institutions.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *Postsecondary Attainment, Attendance, Curriculum, and Performance: Some Results From the NELS:88/2000 Postsecondary Education Transcript Study* (PETS:2000) (Washington, DC, forthcoming).

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of remediation. In 1995, almost all public 2-year institutions offered remedial reading, writing, and mathematics courses; in contrast, 81 percent of public 4-year institutions and 63 percent of private 4-year institutions offered remedial courses in these subjects (Lewis, Farris, and Greene 1996). In 2000, enrollment in remedial mathematics courses accounted for 14 percent of total mathematics enrollment in 4-year institutions and 60 percent in 2-year institutions (Lutzer, Maxwell, and Rodi 2002). Although undergraduate enrollment in remedial mathematics courses in 4-year institutions declined by 16 percent from 1990 to 2000, enrollment in remedial mathematics courses in 2-year institutions increased by 5 percent during the same period (Lutzer, Maxwell, and Rodi 2002). Enrollments in remedial S&E courses are not known.

Conclusion

The United States has recorded some improvement in student mathematics and science achievement since the 1970s. But gains have been modest and were mostly achieved before the 1990s. Students are taking more advanced coursework than in the past, and more students are going on to higher education than in earlier decades.

However, compared with students in other countries, U.S. students are not achieving at high levels, and U.S. students fare worse in international comparisons at higher grade levels than at lower grade levels. Several other developed countries appear to be producing better qualified cohorts of high school graduates and sending as many or more of them on to higher education.

Achievement differences between male and female students have largely disappeared, especially in mathematics. However, substantial gaps persist among different racial/ethnic and income groups. Blacks and Hispanics are achieving at lower levels than whites and Asian/Pacific Islanders, and students in high-poverty schools are doing worse than their peers in low-poverty schools. Coursetaking patterns parallel these achievement patterns, although with greater disparities in some fields (e.g., physical sciences) and smaller ones in others (e.g., advanced biology). Higher proportions of blacks are going on to college than in the past, and the difference between blacks and whites in this respect has narrowed somewhat. But the same is not true for Hispanics.

Schools that serve students from different racial, ethnic, and income groups provide students with differing access to educational resources. Access to challenging courses, qualified and experienced teachers, good learning environments, and learning opportunities that make use of computers and the Internet is unequally distributed, but more so in some respects than in others:

♦ **Course availability.** Differences in access to some mathematics and science courses are modest. High schools with high proportions of low-income students are comparable to other schools in the percentages offering courses in advanced biology, chemistry, and trigonometry/algebra III. Wider gaps exist for physics, but all of these courses are almost universally accessible in U.S. public high schools. However, AP courses are more widely available in high schools with very low proportions of low-income students, and the availability of certain specialized mathematics courses is negatively associated with the percentage of low-income students.

- **Out-of-field teachers.** The extent of inequalities in exposure to out-of-field teachers depends on how out of field is defined and measured. Using a broad definition of out of field (lacking a college major or minor in either the field taught or one of several closely related fields) yields marginal but consistent differences between schools with high and low percentages of low-income or minority students: students in high poverty or high minority schools are slightly more likely to have out-of-field teachers. Using a narrow concept of out of field (lacking a major in the subject taught) yields no substantial difference between schools with different percentages of minority students. Likewise, students taking mathematics and biology/ life science courses have similar chances of encountering teachers who did not major in these subjects regardless of their school's poverty level. The same is not true for physical science students, however, where school poverty is associated with out-of-field teaching. One of the most striking differences in teacher qualifications is that fewer students in heavily minority or low-income schools had mathematics or science teachers who majored in mathematics or science education; although critics have questioned the value of these types of credentials, they appear to be more common in schools with more advantaged students.
- **New teachers.** The percentage of inexperienced mathematics teachers does not vary with school poverty or minority enrollment, but the percentage of inexperienced science teachers does. New mathematics and science teachers in schools with large percentages of students from low-income or minority families had substantially less practice teaching experience before taking on their assignments. Science teachers in these schools were also substantially less likely to participate in an induction program, but only relatively modest differences existed for mathematics teachers. In both subjects, the proportion of teachers who had worked with a mentor did not vary substantially with a school's minority or low-income enrollment.
- **Learning environment.** Teachers had more favorable perceptions of the learning environment in high schools with fewer low-income and minority students. Differences in perceptions varied in size: they were small for questions about administrative practices, larger for questions about available teaching materials and student apathy and disrespect, and largest for questions about parental involvement and student attendance.
- **IT access.** In recent years, IT has rapidly become more available in public schools. Disparities by race/ethnicity and income are much smaller for computer access than for Internet access. Access at home is much more unequally distributed than access at school.

As a result of reform efforts begun in the 1980s and continuing most recently with the NCLB Act, changes are occurring in mathematics and science education. Increasing numbers of states are developing and implementing standards, states and school districts are increasing graduation requirements, and students are being offered (and are taking) more advanced courses. In addition, educators and policymakers are paying increasing attention to teacher professional development and to taking advantage of computers and the Internet in instruction. The NCLB Act has introduced new levels of accountability, requiring schools to demonstrate improvement for all students or face sanctions, thus raising the stakes for all involved.

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Higher Education in Science and Engineering

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Highlights

Structure of U.S. Higher Education

- **The U.S. higher education system provides broad access to varied institutions, which differ in size, type of administrative control (public or private), selectivity, and focus.** The system gives students flexibility in moving between institutions, transferring credits, entering and leaving schools, and switching between full- and part-time status.
- **Research and doctorate-granting universities produce most of the undergraduate engineering degrees (78 percent in 2000) and about half of the degrees in natural, agricultural, and social sciences.** However, master's and liberal arts institutions produce most of the undergraduate degrees in mathematics and computer sciences.
- **A higher percentage of baccalaureate recipients study science and engineering at research universities and selective liberal arts colleges than at other kinds of institutions.** Over the past 30 years, these S&E-focused institutions accounted for a declining percentage of higher education enrollments.
- **Historically black colleges and universities and Hispanic-serving institutions are important sources of S&E bachelor's degrees earned by minority students.** These institutions granted about one-third of all S&E baccalaureates awarded to blacks and Hispanics.
- **The fastest-growing major segment of higher education is community colleges.** These institutions are a bridge for students who want to attend 4-year colleges. Some S&E graduates earned credits at community colleges toward their degrees.
- **Universities and colleges are increasingly using advanced information technology and distance education; however, distance education remains limited in S&E fields.** Fewer than 10 percent of students in S&E fields took courses through distance education.

Enrollment in Higher Education

- **In the late 1990s, the U.S. college-age population reversed its 2-decade-long decline and began an upward trend.** After decreasing from 21.5 million in 1981 to 17.4 million in 1997, the college-age population reached 18.5 million by the 2000 census and is expected to increase to 21.7 million by 2015.
- **Increased enrollment will come from minority groups, principally Hispanics, a group traditionally underrepresented in S&E.** Between 1992 and 1998, overall enrollment increased by 1 percent, that of underrepresented minorities by 16 percent, and that of Asian/Pacific Islanders by 36 percent.
- **Interest in S&E study is high among freshmen, and their coursework preparation to study S&E appears as good as in the past.** However, 20 percent of those intending an S&E major reported needing remediation in mathematics, and 10 percent needed remediation in science.
- **A number of studies find that women and underrepresented minorities leave S&E programs at higher rates than men and white students, resulting in lower degree completion rates for women and underrepresented minorities.**
- **Enrollment in U.S. S&E graduate education peaked at 435,700 in 1993, declined through 1998, and rose to near its record level by 2001.** Graduate enrollment in engineering and computer sciences drove the recent growth, mostly because of foreign students. Enrollment in most other science fields remained level or declined.
- **Fluctuation in graduate S&E enrollment from 1994 to 2001 reflects a decline of 10 percent in enrollment by U.S. citizens and permanent residents, balanced by an increase of nearly 35 percent in foreign graduate S&E enrollment.** A 26 percent drop among white men and 9 percent drop among white women drove the U.S. decline. U.S. minority enrollment increased by 22–35 percent. Foreign enrollment declined from 1992 to 1996, returned to its former level by 1999, and reached an all-time high in 2001.
- **One in five S&E graduate students received primary support from the Federal Government in 2001.** The support was mostly in the form of research assistantships (RAs)—67 percent, up from 55 percent 2 decades earlier—and was offset by declining traineeships. For students supported through non-Federal sources, teaching assistantships were the most prominent mechanism (40 percent), followed by RAs (32 percent).
- **For doctoral students, notable differences exist in primary support mechanisms by sex, race/ethnicity, and citizenship.** Men are most likely to be supported by RAs (38 percent), whereas women are most likely to support themselves from personal sources of funds (34 percent). Whites and Asian/Pacific Islanders are most likely to derive primary support from RAs (26 and 31 percent, respectively), whereas underrepresented minorities depend more on fellowships (36 percent). The primary source of support for foreign doctoral students is an RA (43 percent).

Higher Education Degrees

- **The ratio of bachelor's degrees in natural, agricultural, and computer sciences; mathematics; and engineering (NS&E) to the population cohort stood between 4 and 5 per 100 for several decades but increased to 5.7 in the late 1990s,** largely on the strength of increases in the number of computer science baccalaureates.

- **The annual output of S&E bachelor's degrees rose steadily from 303,800 in the mid-1970s to 398,600 in 2000.** They represented approximately one-third of all baccalaureates for the period. These consistent trends mask considerable variations among fields.
- **Over the past quarter-century, women and members of minority groups earned greater proportions of S&E bachelor's degrees, as the percentage of degrees earned by white students declined from 87 to 68 percent.** By 2000, women earned half the degrees, up from one-third. Degrees awarded to underrepresented minorities rose from 9 to 16 percent, and those awarded to Asian/Pacific Islanders increased from 2 to 9 percent.
- **Despite the considerable progress of underrepresented minorities in earning bachelor's degrees between 1990 and 2000, the gap in educational attainment between these groups and whites remains wide, especially in S&E fields.** In 2000, underrepresented minority groups earned 17.9 percent of any type of college degree per 100 24-year-olds, about half the ratio earned by whites. The gap between these minorities and whites is even larger for NS&E degrees.
- **Increasing numbers of S&E doctoral degree recipients are women, minorities, or foreign; the share of U.S. whites decreased from 71 percent in 1977 to 50 percent in 2001.** The share of doctorates awarded to U.S. citizens declined from 77 to 59 percent.
- **Noncitizens accounted for most of the growth in U.S. S&E doctorates from the late 1980s through 2001.** Their annual growth rate for earning degrees during this period was 3 percent, approximately three times that for U.S. citizens.

Foreign Doctoral Degree Recipients

- **From 1985 to 2001, students from China, Taiwan, India, and South Korea earned more than half of the 148,000 U.S. S&E doctoral degrees awarded to foreign students, which is four times the number awarded to students from Europe.**
- **Nearly 30 percent of the actively employed S&E doctorate holders in the United States are foreign born, as are many postdocs.** Most foreign-born doctorate holders working in the United States obtained their degrees in the United States.
- **Foreign students earning U.S. S&E doctorates are increasingly planning to stay in the United States after degree receipt.** In the period 1998–2001, 76 percent of foreign doctoral degree recipients in S&E fields planned to stay in the United States, and 54 percent had firm offers to do so.
- **Stay rates vary by place of origin, with many Chinese and Indian students staying and most South Korean and Taiwanese doctoral degree recipients leaving after degree receipt.** Stay rates of graduates from France, Italy, and Germany have increased well above their long-term average; stay rates of Eastern European doctoral degree recipients are exceeded only by those of Indian doctoral degree recipients.

International S&E Higher Education

- **In the 1980s and 1990s, the college-age cohort decreased in all major industrialized countries, although at different times, with different durations, and to varying degrees.** To produce enough S&E graduates for increasingly knowledge-intensive societies, industrialized countries have encouraged a higher proportion of their citizens to obtain a higher education, have trained a higher proportion in S&E, and have recruited S&E students from other countries, especially from the developing world.
- **Although the United States has historically been a world leader in providing broad access to higher education, many other countries now provide comparable access.** The U.S. ratio of bachelor's degrees earned to the college-age population remains high (33.8 per 100 in 2000). However, nine other countries now provide a college education to approximately one-third or more of their college-age population, and others are expanding access.
- **The proportion of the college-age population earning NS&E degrees is substantially higher in more than 16 locations in Asia and Europe than in the United States.** In the United States, the ratio has gradually increased from between 4 and 5 to 5.7 per 100 over 3 decades. South Korea and Taiwan increased their ratios from 2 per 100 in 1975 to 11 per 100 in 2000–01, and several European countries have doubled and tripled their ratios, reaching figures between 8 and 11 per 100.
- **The 1990s witnessed a worldwide increase in the number of students going abroad for higher education study to the well-established universities in the United States, United Kingdom, and France, with the largest increases at the graduate level in S&E fields.** However, universities in other countries, including Japan, Canada, and Germany, also expanded their enrollment of foreign S&E graduate students.
- **The proportion of doctoral S&E degrees earned by foreign students, particularly in engineering, mathematics, and computer sciences, is increasing in the major host countries.** In 2001, noncitizens earned 56 percent of the doctoral engineering degrees awarded in the United States, 51 percent in the United Kingdom, and 22 percent in France. They earned 49 percent of the mathematics and computer science doctorates awarded in the United States, 44 percent in the United Kingdom, and 29 percent in France.

Introduction

Chapter Overview

Modern societies are committed to fostering economic growth through scientific and technological innovations developed by an educated workforce trained in institutions of higher education. In the United States and around the world, such institutions have expanded to enroll and graduate increasing numbers of students in science and engineering at all levels.

Scientific, technological, and demographic changes are altering the face of higher education. As science changes to become more interdisciplinary and mathematical, higher education must adapt to demands for new skills. Information technology (IT) facilitates new, more flexible modes of delivering higher education and, by making scientific data more readily accessible to students, opens new possibilities for learning. Demographically, college-age cohorts have grown smaller in the major industrialized countries. Young, native-born males, typically a prime source of S&E graduates, are a smaller proportion of the college population. In the United States, higher education increasingly serves women and minorities—groups that are historically underrepresented—and older students, among S&E graduates. Colleges and universities confront the challenge of training students from these hitherto underrepresented groups.

Foreign students are playing an increasing role in higher education throughout the industrialized world. U.S. higher education has benefited from an influx of foreign S&E enrollees, who play a large role in graduate education and as research and teaching assistants on U.S. campuses. Many of them remain in the United States and become part of the workforce. Whether more stringent security measures in the wake of the events of September 11, 2001, will affect the role of foreign students is yet unknown.

Chapter Organization

This chapter describes some characteristics of the U.S. institutions that deliver higher education, paying special attention to new and emerging practices and institutional forms. It then profiles the students who enroll in higher education and receive degrees, especially in S&E, disaggregating the data by sex, field of study, race/ethnicity, and citizenship at the various levels of education. Because doctoral-level scientists and engineers are so important to science and technology (S&T) innovation and competitiveness, a section is devoted to the flow of doctoral students to the United States and back to their countries of origin. The chapter closes by considering patterns and trends in degree production in other countries, especially those that are advanced and rapidly advancing.

Structure of U.S. Higher Education

The U.S. higher education system provides broad access to varied institutions, which differ in size, type of administrative control (public or private), selectivity, and focus. (See sidebar, "Carnegie Classification of Academic Institutions.") The system gives students flexibility in moving between institutions, transferring credits, entering and leaving schools, and switching between full- and part-time status.

Nonprofit degree-granting institutions that offer face-to-face classroom education continue to dominate U.S. higher education. These traditional institutions have incorporated new modes of education delivery, through IT and distance education, into their repertoires. New institutional forms that feature control by profit-making firms, certificate programs designed to enhance specific skills, and primary reliance on distance education, alone or in combination, have also

Carnegie Classification of Academic Institutions

Research I and II universities offer a full range of baccalaureate programs and graduate education through the doctorate level, award 50 or more doctoral degrees a year, and receive at least $15.5 million in Federal research support annually.

Doctorate-granting I and II institutions offer a full range of baccalaureate programs and graduate education through the doctorate level but in a narrower range than the research universities. They award at least 20 doctoral degrees in at least three disciplines; no Federal research fund limit is required.

Master's (comprehensive I and II) institutions offer a broad range of baccalaureate programs and, generally, graduate education through the master's degree. The latter often focuses on occupational or professional disciplines such as engineering or business administration. Minimum enrollment is 1,500 students.

Baccalaureate (liberal arts I and II) colleges are mostly 4-year institutions focused on awarding a bachelor's degree. A few highly selective colleges award more than 40 percent of their baccalaureates in liberal arts and science fields.

Associate of arts (2-year) colleges offer certificate or degree programs through the associate's degree level and, with few exceptions, offer no bachelor's degrees.

Professional and other specialized schools offer various degrees, including doctorates, but they specialize in religious training; medicine and health; law; engineering and technology; business and management; art, music, and design; and education. The category also includes corporate-sponsored institutions.

emerged in recent years. However, these new forms still play a limited role in S&E education.

Institutions Providing S&E Education

The U.S. higher education system consists of approximately 3,700 degree-granting colleges and universities that served about 15.6 million students and awarded 2.3 million degrees in 2000. Almost one-quarter of the degrees were in S&E fields (appendix tables 2-1, 2-2, 2-3, and 2-20).

Figure 2-1 shows the distribution of institutions, enrollment, degrees, and research and development expenditures across the different types of academic institutions. The institutions are classified according to a typology published by the Carnegie Foundation for the Advancement of Teaching 1994.[1] The typology groups institutions on the basis of the type and breadth of their programs, the volume of doctoral degrees conferred, the amount of Federal R&D funding, and their selectivity in the early 1990s.

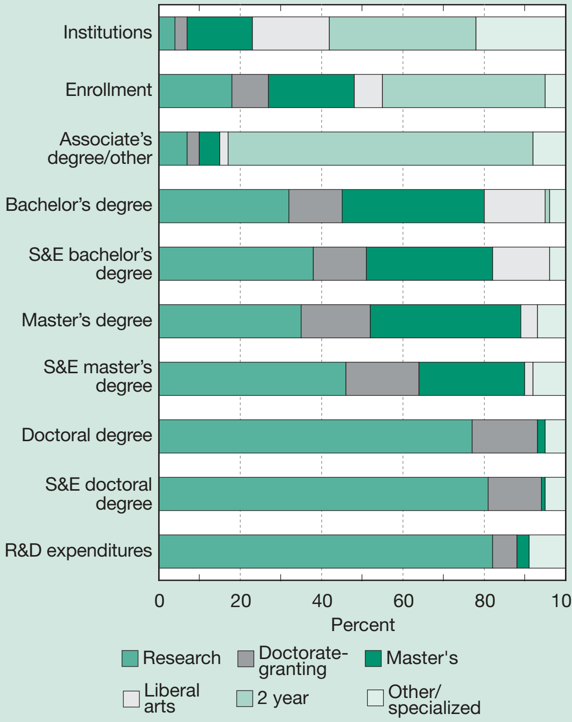
Although research and doctorate-granting universities award most of the S&E baccalaureates, students earn such degrees at all kinds of institutions. In different S&E fields, the role of different kinds of institutions varies. Research and doctorate-granting universities produced most of the undergraduate engineering degrees (78 percent in 2000) and about half of the degrees in natural and agricultural sciences and in social and behavioral sciences. However, master's and liberal arts institutions produce most of the undergraduate degrees in mathematics and computer sciences (figure 2-2).

A higher percentage of baccalaureate recipients studied S&E at research universities and selective liberal arts colleges than at other kinds of institutions. However, over the past 30 years, these S&E-focused institutions accounted for a declining percentage of higher education enrollment (appendix table 2-2). Master's and doctoral degrees were concentrated in research and doctorate-granting universities (appendix table 2-3).

The fastest-growing major segment of higher education is community colleges. These institutions are a bridge for students who want to attend 4-year colleges, and some S&E graduates earn credit at community colleges toward their degrees (Bailey and Averianova 1999). Community colleges also offer remedial courses and services and enroll millions of students in noncredit and workforce training classes. Enrollment in remedial courses often includes many older adults taking refresher courses (American Association of Community Colleges 2001).

Some traditional colleges and universities educate a disproportionate share of undergraduate racial/ethnic minorities, including historically black colleges and universities (HBCUs), Hispanic-serving institutions (HSIs), tribal colleges and universities (TCUs), and postsecondary minority institutions. In 1998, 29 percent of the blacks who received S&E bachelor's degrees earned them at HBCUs. About one-third of Hispanics who earned S&E bachelor's degrees did so at HSIs. Only six TCUs are 4-year colleges or universities; the rest are 2-year schools. Of the six TCUs that offer bachelor's degrees, two offer baccalaureates in S&E fields (NSF/SRS 2003c).[2]

Figure 2-1
Distribution of selected aspects of U.S. higher education, by Carnegie type of institution: 2000



NOTE: Other includes first professional degrees and all types of graduate and undergraduate certificates.

SOURCES: U.S. Department of Education, Enrollment and Completion surveys; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix tables 2-1, 2-2, and 2-3.

Science & Engineering Indicators – 2004

New Modes of Instructional Delivery

Institutions of higher education are increasingly using advanced IT and distance education and are exploring the best ways to use these recent innovations to improve S&E education.

IT in Traditional Institutions

Advances in IT have provided scientists with powerful tools to amass and manipulate large databases and to solve previously intractable problems requiring complex calculations. Computer laboratories can bring advanced research to undergraduates via simulations. (See sidebar, "IT in Forest Ecology.") U.S. institutions of higher education are developing

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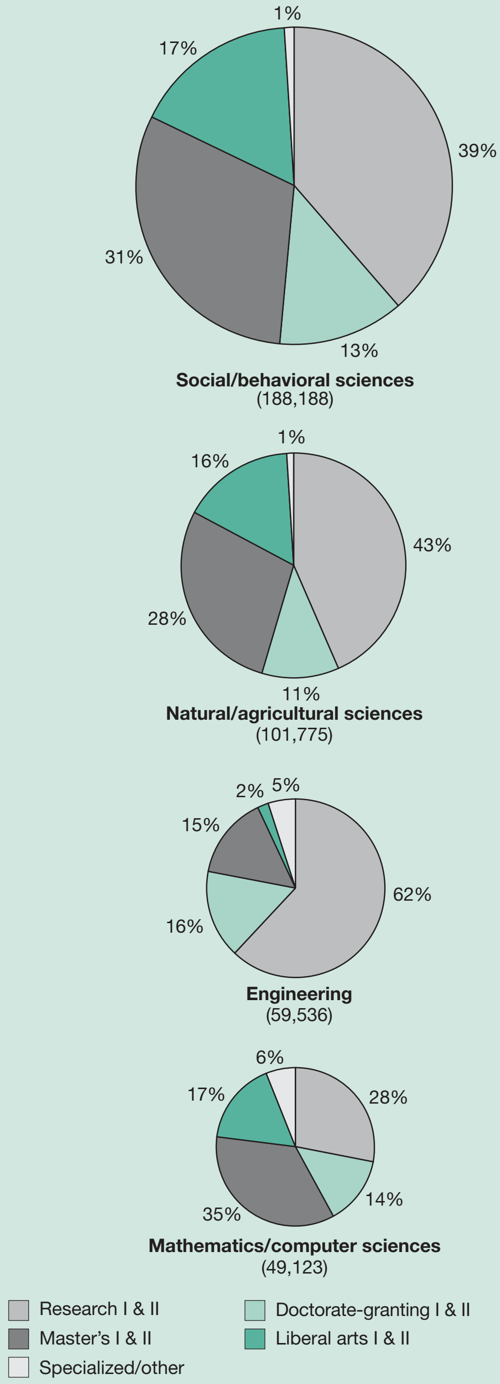
[1] The 2000 Carnegie Classification is under review, and a series of distinct classification schemes is expected to be introduced in 2005. http://www.carnegiefoundation.org/Classification/future.htm.

[2] The U.S. Department of Education, Office of Civil Rights, has definitions and a list of minority-serving institutions at http://www.ed.gov/offices/OCR/minorityinst.html.

Figure 2-2
S&E bachelor's degrees, by field and institution type: 2000



NOTES: Natural sciences include physical, biological, earth, atmospheric, and ocean sciences. Two-year institutions award a few S&E bachelor's degrees, included in totals by field. Number of degrees in parentheses.

SOURCES: U.S. Department of Education, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-3.

Science & Engineering Indicators – 2004

IT in Forest Ecology

Hampshire College (Amherst, MA) designed two computer programs, SimForest B and G, that enable users to simulate forest growth and composition over extended periods under various conditions controlled by the user. SimForest B simulates tree and forest growth, the succession of species over time, and the effects of environmental and man-made disturbances over time. The students set environmental parameters such as rainfall, temperature, soil fertility, soil texture, and soil depth. They plant a plot of trees from a list of more than 30 species and then run the simulation and observe the trees as they grow and the forest evolves. SimForest G lets students and faculty explore and manipulate the program that drives SimForest B, thus affording students a greater opportunity to explore modeling as a tool for understanding complex environments. Such simulations of long-term ecological effects enable students to run experiments that encompass the randomness, complexity, and emergent phenomena observed in nature. The material is available on the Hampshire College site at http://ddc.hampshire.edu/simforest.

the IT infrastructure needed for computer-driven classes. In 2002, more than half of the classes in colleges used Internet-based resources, about one-third had Web-based pages for courses, and rates of e-mail use in all college classes were close to 70 percent. In addition, campuses are investing in wireless networks. Nearly 70 percent of the campuses responding to the 2002 Campus Computing Survey indicated that wireless networks were functioning in at least some part of their campus (Green 2002).

Distance Education

Distance education has been a significant feature of higher education for more than 60 years. Until the advent of electronic means of easy communication, distance education was mainly conducted through the mail, either as correspondence courses offered by traditional universities or as certification programs offered by for-profit correspondence schools. As electronic technology evolved, so did the principal means of delivery of distance education, advancing from courses delivered by radio (in the 1930s), television (in the 1950s), audio- or videocassettes (in the 1970s and 1980s), and computer and videoconferencing via satellite (in the 1990s) to the Internet, the most popular form of delivery from the 1990s to the present.

Distance education in U.S. colleges and universities expanded dramatically in the late 1990s, according to a nationally representative survey taken in 2000–01 (U.S. Department of Education 2003b). Both enrollment in for-credit distance education courses and the number of courses offered more than doubled from 1997–98 to 2000–01: enrollment grew from 1.3 million to 2.9 million, and course offerings grew from 47,500 to 118,000. In 2000–01, 56 percent (2,320) of 2- and 4-year institutions offered distance education courses, up from 44 percent 3 years earlier. However, percentages were much higher in public institutions. Almost 90 percent of public 2-year and 4-year institutions offered distance education courses; 16 percent of private 2-year and 40 percent of private 4-year institutions offered such courses. Still, fewer than 10 percent of students in S&E fields took courses through distance education.

Various technologies were used in delivering these distance courses. Ninety percent of the institutions offering distance education courses used online technologies such as the Internet and e-mail. A smaller percentage offered live interactive technologies, such as computer (43 percent) or video (51 percent) conferencing.

Rather than replacing traditional institutions, distance education enables these institutions to reach a wider audience for higher education. A National Center for Education Statistics (NCES) study on distance education conducted in 1999–2000 found that students taking advantage of distance education opportunities tended to be older (e.g., undergraduates age 24 years and older), have family responsibilities, and have limited time. They were more likely to be enrolled in public 2-year colleges, attend school part time, and work full time while enrolled (U.S. Department of Education 2003a).

Offering S&E courses through distance education has challenges and benefits. For example, one challenge is in equating experiences in virtual or online laboratories with traditional class laboratories. (See sidebar, "Distance Education: Problems and Successes.")

Distance Education: Problems and Successes

Problems with distance education, including accreditation, student assessment, course stability, international implementation, and delivery of laboratory courses online, occur in both traditional and nontraditional institutions.

The pace of introduction and use of distance education courses in online institutions, particularly for-profit institutions, has created some challenges in accreditation and transferability of courses. Although online institutions may be accredited by national agencies such as the Council for Higher Education Accreditation, they often have difficulty gaining accreditation by regional accreditation agencies, and thus the courses may not be accepted by more conventional universities. Online institutions report that they face a tougher problem in this aspect of accreditation than traditional institutions (Council for Higher Education Accreditation 2002 and Regional Accrediting Commissions 2001).

Allied to these problems is the difficulty of designing appropriate means by which to assess student performance, particularly in laboratory courses (Valentine 2002). For example, the Accreditation Board for Engineering and Technology is beginning to design standards for engineering laboratories and, with the help of the Alfred P. Sloan Foundation, is using a few test institutions to determine the usefulness of these standards when applied to courses delivered online (Feisel and Peterson 2002).

Some online science courses in chemistry and biology include simulated laboratories or base their laboratories on materials easily obtained from local sources. Although some of these laboratories have been successful, it is too early to tell whether these offerings will be equivalent to more conventional laboratories.

Successes and Failures

There have also been mixed signals about the stability of courses offered through small or large consortia. The newly initiated eArmyU, designed for traveling servicemen and -women, benefits from a well-organized base from which courses are offered. It recruits a cadre of institutions to offer courses and agree to standards for transferability (Arnone 2002). As of January 2003, 32 colleges were participating, offering more than 100 degree programs and enrolling more than 30,500 soldiers. Enrollment is expected to increase to 80,000 by 2005 (Carnevale 2003). For-profit ventures by conventional institutions do not appear to be faring as well. In January 2003, after 2 years of operation, Columbia University closed Fathom, its for-profit online learning venture that had been designed to sell Web-based courses and seminars to the public. This followed the demise of other ventures at New York University, Temple University, and the University of Maryland, College Park (Carlson 2003).

International Programs

Plans for offering international degree programs face major implementation difficulties. The University of Michigan recently abandoned its attempts to team with Shanghai Jiao Tong University to offer master's degrees in engineering to Chinese students through distance learning. The program was designed for evening and weekend courses, with the hope that Shanghai-based multinational companies (e.g., Whirlpool, General Motors, and Delphi) would be willing to pay to train local employees. However, although 20 students were expected, only 2 enrolled in the first year. Deterrents included high tuition and the fact that a degree from an American university, even from a prestigious institution like the University of Michigan, has less value if not combined with actual experience in the United States (Liu 2002).

New Types of Institutions

Certificate programs, for-profit colleges and universities, and various forms of industrial learning centers play a small but growing role in S&E higher education. Programs that award certificates have become an increasingly popular method for students and S&E professionals to learn a particular skill or expand their interest to a related field and to have their knowledge documented. General characteristics of graduate certificate programs are a focus on practical skills (e.g., hazardous waste management and infection control); fewer course requirements than for a master's degree (three to six specific courses); and, typically, an interdisciplinary scope (e.g., environmental ethics). Certificates represent a university's flexibility in a changing environment and an industry's need to upgrade the skills of its workers in emerging and rapidly changing fields. Although they are most commonly offered in health sciences, education, business, and IT, certificate programs are also offered in social sciences, environmental studies, engineering, and other sciences (Patterson 2001).[3]

Providers include 2- and 4-year colleges and universities of all types and the education units of various corporations (e.g., Microsoft, Cisco, Oracle, and Novell). In 2002, approximately 500 universities offered graduate certificate programs, up from 40 in 1997 (Patterson 2002). In some cases, the coursework may be applied to a degree program. Community colleges are also an important source of S&E-related certificate programs, particularly in health and computer sciences. In 2000, community colleges represented almost half of the academic providers of IT-related certificates.

Certificates can be earned through onsite or distance education and in some programs, particularly in IT, are awarded on completion of a skill-based exam, requiring no specific coursework. A Department of Education study in 2000 showed strong growth in exam-based certificates for the IT industry in the 1990s, extending well beyond the United States (U.S. Department of Education 2000b). In 1999, 5,000 sites in 140 countries were administering an estimated 3 million assessments in 25 languages. More than 300 discrete certifications have been established since 1989, when the first IT certificate (Certified Novell Engineer) was issued.

The percentage of students enrolled in for-profit institutions remains small, even though the number of institutions is growing. The Community College Research Center (CCRC) found that student enrollment in for-profit 2-year institutions accounted for 4 percent of total enrollment in 2-year institutions (Bailey, Badway, and Gumport 2003). Among 4-year institutions, the for-profit enrollment share was less than 2 percent. A report of the Education Commission of the States found that between 1989 and 1999, the number of for-profit 2-year degree-granting institutions grew 78 percent, representing 28 percent of all 2-year institutions in 1999. During the same period, the number of for-profit 4-year institutions grew by 266 percent (Bailey, Badway, and Gumport 2003).

Certificates accounted for 57 percent of all degrees awarded by U.S. for-profit 2-year institutions, which was more than awarded by public 2-year institutions (35 percent) (Bailey, Badway, and Gumport 2003). On the basis of case studies of three public community colleges and a for-profit chain, CCRC concluded that for-profit 2-year institutions are more appropriate for students interested in a narrowly focused career in a technical field, and community colleges are better suited to students who are interested in a general education or undecided on a major.

From 1988 to 2001, corporate "universities" grew from 400 to 2,000 (National Research Council 2002). Most of them primarily offer noncredit, nondegree courses narrowly targeted at retraining the workforce and other company needs. However, some large industries have internal training at a higher education level in engineering and design. For example, Motorola University contracts with 1,200 faculty worldwide who teach business and engineering wherever Motorola is designing innovative products.

Independent nonprofit institutions are also emerging to provide training geared specifically to corporate needs. These institutions offer credit-bearing courses and degree programs through IT and distance education. Institutions such as the Western Governors University and the United States Open University are recently formed examples. Since 1984, the National Technological University (NTU), a consortium of some 540 institutions, has been developing and offering courses and degree programs for engineering-oriented companies. The programs target engineering professionals interested in obtaining master's degrees in 1 of 18 engineering, technical, or business areas. All 1,300 academic courses offered by NTU are supplied by 52 leading engineering universities, including 25 of the top engineering schools in the country (National Research Council 2002).

For-profit and nonprofit subsidiaries of institutions and partnerships between 4-year institutions and private companies comprise a third type of industry learning center. The University of Maryland, College Park and eCornell are examples of for-profit or nonprofit subsidiaries of postsecondary education institutions. Both offer credit and noncredit courses to individuals and corporate universities. Motorola has partnerships with traditional institutions for sharing technology, faculty, and facilities. Motorola is part of a Ph.D. program at the International Institute of Information Technology (formerly the Indian Institute of Information Technology) in Hyderabad, India, and degree programs at Morehouse College in Atlanta, Georgia, and Roosevelt University in Chicago, Illinois (Wiggenhorn 2000).

Enrollment in Higher Education

Overall Enrollment

Overall enrollment in U.S. institutions of higher education increased from about 7 million in 1967 to 14.5 million in 1992, remained at that level until 1997, and rose to 15.6

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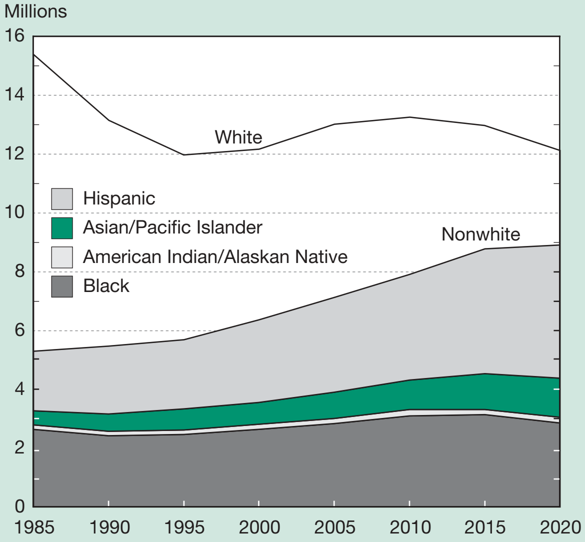
[3] A listing of graduate certificate programs can be found at http://www.certificates.gradschools.com.

million by 2000. These increases differed for various groups (table 2-1 and appendix table 2-2). Enrollment is projected to increase in the first 2 decades of the 21st century for two reasons. First, the number of students of college age (approximated by the size of the 20–24-year-old cohort) is projected to grow. In the late 1990s, the U.S. college-age population reversed its 2-decade-long decline and began an upward trend. After decreasing from 21.5 million in 1981 to 17.4 million in 1997 (about 19 percent), the college-age population reached 18.5 million by the 2000 census and is expected to increase to 21.7 million by 2015 (appendix table 2-4).[4] Second, increasing numbers of students who are older than 24 years are enrolling in higher education. More than 50 percent of all undergraduates are 22 or older; almost 25 percent are 30 or older (Edgerton 2001).

The increased enrollment is projected to come from minority groups, principally from Hispanics, a group that has not traditionally studied S&E fields to the same extent as the majority white population. (See "Undergraduate Enrollment in S&E.") From 2000 to 2015, the Hispanic college-age population is projected to increase by 52 percent, nearly as high as the rise in Asian/Pacific Islanders (62 percent); those of blacks and American Indian/Alaskan Natives will rise by 19 and 15 percent, respectively. The white college-age cohort, which declined until 2000, is expected to rise by 7 percent, should expand slowly until about 2010, and should then decline again (figure 2-3 and appendix table 2-4).

The changing demographic composition of higher education can already be seen by comparing 1992 and 1998 data. During this period, overall enrollment increased by 1 percent, but underrepresented minority enrollment grew by 16 percent and Asian/Pacific Islander enrollment by 36 percent. In 1998, underrepresented minority students were more often enrolled than U.S. citizens overall in 2-year institutions (43 versus 39 percent) and less often in research institutions (12 versus 18 percent). (For a breakout of enrollment trends by institutional type and race/ethnicity in the 1990s, see appendix table 2-5.)

Figure 2-3
U.S. population of 20–24-year-olds, by race/ethnicity: Selected years, 1985–2020



SOURCES: U.S. Bureau of the Census, Population Division, 1990 Census; and U.S. Bureau of the Census, Population Projections Program, *Projections of the Resident Population by Age, Sex, Race, and Hispanic Origin: 1999 to 2100.* See appendix table 2-4.

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Undergraduate Enrollment in S&E

Enrollment in undergraduate S&E courses and majors prepares students to study S&E at more advanced levels. It also prepares them to work in occupations that require the knowledge and skills acquired in the pursuit of an S&E education.

Table 2-1
Growth in higher education enrollment, by sex, race/ethnicity, and visa status: 1986–98
(Index: 1986 = 100)

Sex, race/ethnicity, and visa status	1986	1989	1992	1995	1998
All students	100	108	116	114	116
Male	100	101	111	108	108
Female	100	110	120	120	123
White	100	108	112	106	105
Asian	100	124	161	184	208
Underrepresented minorities	100	114	138	150	165
Black	100	112	131	138	149
Hispanic	100	117	147	167	188
American Indian/Alaskan Native	100	111	136	150	165
Temporary resident	100	112	133	135	132

NOTE: Race/ethnicity breakdown does not include temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov.

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[4] For data on earlier years, see appendix table 2-32.

Table 2-2
Freshmen who took recommended college-preparatory courses in high school, by intended major: 1983 and 2001
(Percent)

Course	Minimum years taken	Non-S&E major 1983	Non-S&E major 2001	S&E major 1983	S&E major 2001
English	4.0	93.9	97.8	94.6	97.9
Mathematics	3.0	87.3	97.8	94.9	98.6
Foreign language	2.0	70.6	92.4	75.2	93.5
Physical sciences[a]	2.0	51.7	55.2	66.1	63.1
Biological sciences	2.0	35.8	43.2	35.6	45.7
Computer sciences	0.5	51.6	61.6	63.8	63.6

[a] Physical sciences include physics, chemistry, astronomy, and earth, atmospheric, and ocean sciences.

SOURCE: Higher Education Research Institute, University of California at Los Angeles, Survey of the American Freshman: National Norms, special tabulations, 2003.

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Freshmen Intentions to Major in S&E

The annual freshman norms survey, administered by the Higher Education Research Institute (HERI), indicates the distribution of future S&E (and other) bachelor's degrees. Since 1972, the survey has asked freshmen at numerous universities and colleges about their degree intentions, and the data have given a general picture of degree trends several years later.[5]

According to the HERI survey, freshmen from all demographic groups plan to study S&E. In recent years, approximately 31 percent of white, 43 percent of Asian/Pacific Islander, and 35 percent of underrepresented minority freshmen reported that they intended to major in S&E. The proportions were higher for men in every racial/ethnic group. In the 1990s, more men from every racial/ethnic group reported interest in a computer science major than before. However, in 2001 and 2002, the number of freshman intending to major in computer sciences dropped off for every race and ethnicity (appendix table 2-6).

The growing diversity of the college population is mirrored in the changing mix of students studying S&E. Women constituted 33 percent of students reporting S&E intentions in 1972, rising gradually to 44 percent by the late 1990s. The data also show increasing racial/ethnic diversity among freshmen intending to pursue an S&E major. By 1996, members of underrepresented minority groups accounted for almost 20 percent of those planning an S&E major, up from 8 percent in the early 1970s. After 1996, the percentages for underrepresented minorities fluctuated around 19 percent, with shifts among S&E fields. In the late 1990s, more underrepresented minorities intended majors in biological/agricultural and social/behavioral sciences, and fewer intended majors in computer sciences and engineering (appendix table 2-7).

Few of those intending an S&E major consider teaching as a probable career, whether at the elementary, secondary, or college level. In the past decade, fewer anticipated becoming engineers or scientific researchers than in previous decades. Instead, more anticipated becoming computer scientists or physicians.

Based on coursetaking, survey responses indicate that freshmen are at least as ready for college-level coursework as in the past. Respondents reported taking more of the recommended college-preparatory high school courses than in prior years (table 2-2). However, 20 percent of the 2002 respondents intending an S&E major reported needing remediation in mathematics, and nearly 10 percent reported needing remediation in the sciences. These percentages have been relatively stable over 2 decades (appendix table 2-8). Need for remediation varied depending on the major field: fewer intending to major in mathematics, physical sciences, or engineering reported a need for remediation compared with those intending to major in social or behavioral sciences or in non-S&E fields (figure 2-4).

Retention in S&E

Students change their majors during their undergraduate years or after completing an S&E degree, and S&E fields are not alone in experiencing attrition between freshman intentions and undergraduate outcomes. Two studies of student retention in S&E cast some light on what happens between declaration of a degree intention and the moment a degree is awarded. Retention in S&E careers or in advanced education of those who complete S&E degrees is shown in the National Science Foundation (NSF) National Survey of Recent College Graduates (NSRCG).

An NCES longitudinal study followed first-year students in 1990 who intended to complete an S&E major and found that fewer than half had completed an S&E degree within 5 years. Approximately 20 percent of the students dropped out of college, and the others chose other fields (U.S. Department of Education 2000a). The study also found that underrepresented minorities were more likely than students from other groups to drop out of S&E programs. NCES

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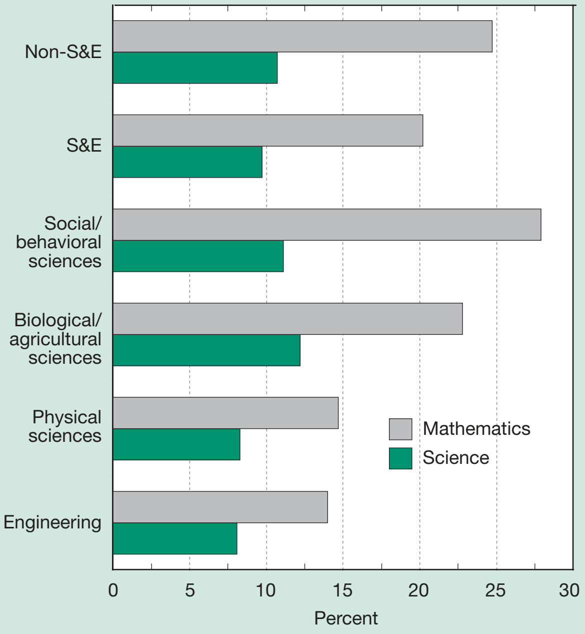
[5] The number of S&E degrees awarded to a particular freshmen cohort is lower than the number of students reporting such intentions and reflects losses of students from S&E, students moving into S&E after their freshman year, and general attrition from bachelor's degree programs. See "Retention in S&E."

Figure 2-4
Freshmen reporting need for remediation in mathematics or science, by intended major: 2002



NOTE: Physical sciences include physics, chemistry, astronomy, and earth, atmospheric, and ocean sciences.

SOURCE: Higher Education Research Institute, Survey of the American Freshman: National Norms. See appendix table 2-8.

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did not collect data on students who moved into S&E from other fields.

A more recent study focused on 1993 freshmen with a declared S&E major at 175 universities and colleges varying in size, selectivity, and highest degree level (Center for Institutional Data Exchange and Analysis 2001). Like the NCES study, this study found that fewer than half of the students had completed an S&E degree after 6 years. It also documented that women and underrepresented minorities left S&E programs at higher rates than men and nonminority students, resulting in lower degree completion rates for women and minorities. Retention rates for those who had declared an intention to major in S&E were higher at institutions that shared the characteristics of high selectivity, low part-time attendance, doctoral degree level, and private governance.

The NSRCG shows retention in S&E as measured through further education and S&E occupations. About one-third of those who graduated with an S&E bachelor's degree in 1999 or 2000 were continuing in S&E in 2001, either in graduate study (13 percent) or employment (20 percent).[6] Percentages of those going on for advanced study in S&E were higher for those with a high grade point average (GPA). More than 18 percent of those with a 3.75–4.00 undergraduate GPA continued to study S&E. In contrast, relatively few (7 percent) of those with less than 2.75 GPA continued to study S&E. Retention rates in S&E from the 2001 survey were up slightly from the 1995 survey (appendix table 2-9).

Retention in S&E after completion of an S&E master's degree was higher than after completion of a bachelor's degree. In 2001, around 63 percent of those who earned an S&E master's degree in 1999 or 2000 were continuing in S&E, either in school (17 percent) or in employment (46 percent). Overall, S&E retention after a master's degree in 2001 was similar to that in 1995, but a larger percentage of these graduates were employed in S&E fields in 2001 than in 1995, and a small percentage were continuing advanced studies in S&E fields (appendix table 2-9).

Enrollment Trends in Mathematics and Statistics

Mathematics and statistics are increasingly important as analytic tools across the sciences. The Conference Board of Mathematical Sciences compiles data every 5 years on enrollment in mathematics and statistics courses (Lutzer, Maxwell, and Rodi 2002). Enrollment in 4-year institutions reached a low in 1995 but rebounded in 2000. Course-level differences were reflected in the degree of recovery. In universities and 4-year colleges, the number of students increased primarily in introductory mathematics and statistics courses. However, more students than before also enrolled in level 1–4 calculus courses. Enrollment in advanced undergraduate courses rose only slightly from the 1995 low, but because completion of the calculus series is a prerequisite for such courses, enrollment in advanced courses is expected to increase after 2000 (table 2-3).

In the past 2 decades, the proportion of enrollment in remedial mathematics courses increased at 2-year institutions and declined at 4-year institutions. In 2000, enrollment in remedial mathematics courses accounted for 60 percent of all mathematics enrollment in 2-year institutions, up from 48 percent in 1980. In the same period, enrollment in remedial mathematics courses at 4-year institutions declined to 14 percent of total mathematics enrollment, down from 16 percent in 1980. Neither of these trends is a reliable indicator of changes in student preparation, however. In general, enrollment in remedial courses includes many older adults taking refresher courses (Phillippe and Patton 1999), a phenomenon that is widespread at 2-year institutions. The decline at 4-year institutions may reflect the effort of some states to remove remedial courses from their 4-year colleges and universities.

Enrollment Trends in Engineering

Generally, engineering programs require students to declare a major in the first year of college, making enrollment data an early indicator of both future undergraduate engineering degrees and student interest in an engineering career. The Engineering Workforce Commission (2003)

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[6] Many occupations not classified as S&E (e.g., elementary/secondary school teacher, manager) require significant scientific or technical background. See "How Are People With an S&E Education Employed?" in chapter 3.

Table 2-3
Estimated enrollment in undergraduate mathematics and statistics courses: 1980–2000

Institution and course level	1980		1985		1990		1995		2000	
	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent
4-year institutions										
All mathematics	1,525	100.0	1,619	100.0	1,619	100.0	1,469	100.0	1,614	100.0
Remedial	242	15.9	251	15.5	261	16.1	222	15.1	219	13.6
Introductory	602	39.5	593	36.6	592	36.6	613	41.7	723	44.8
Calculus	590	38.7	637	39.3	647	40.0	538	36.6	570	35.3
Advanced	91	6.0	138	8.5	119	7.4	96	6.5	102	6.3
Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
All statistics	NA	NA	NA	NA	169	10.4	208	14.2	245	15.2
Elementary	NA	NA	NA	NA	117	7.2	164	11.2	190	11.8
Upper level	NA	NA	NA	NA	52	3.2	44	3.0	55	3.4
2-year institutions										
All mathematics	925	100.0	900	100.0	1,241	100.0	1,384	100.0	1,273	100.0
Remedial	441	47.7	482	53.6	724	58.3	800	57.8	763	59.9
Introductory	180	19.5	188	20.9	245	19.7	295	21.3	274	21.5
Calculus	86	9.3	97	10.8	128	10.3	129	9.3	106	8.3
Advanced	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other	218	23.6	133	14.8	144	11.6	160	11.6	130	10.2
All statistics	28	3.0	36	4.0	54	4.4	72	5.2	74	5.8
Elementary	28	3.0	36	4.0	54	4.4	72	5.2	74	5.8
Upper level	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA not available

NOTES: The curriculum of course levels differs between 2-year mathematics programs and 4-year mathematics departments. However, remedial courses generally include high school-level courses in elementary and intermediate algebra and geometry. Introductory mathematics courses include college algebra, trigonometry, precalculus, and courses for non-science majors. Other mathematics courses in 2-year programs include linear algebra, discrete and finite mathematics, probability, and mathematics for liberal arts majors and prospective elementary school teachers.

SOURCE: D. J. Lutzer, J.W. Maxwell, and S.B. Rodl. *Statistical Abstract of Undergraduate Programs in the Mathematical Sciences in the United States, Fall 2000 CBMS Survey,* (Washington, DC: American Mathematical Society, 2002).

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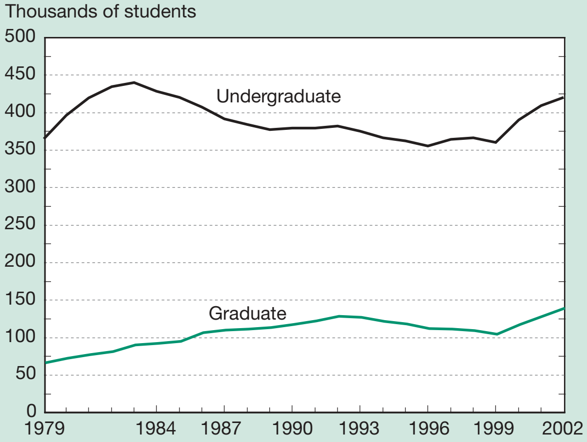
administers an annual fall survey that tracks enrollment in undergraduate and graduate engineering programs.

Undergraduate engineering enrollment decreased sharply during the 1980s, followed by slower declines in the 1990s and rising numbers from 2000 to 2002 (figure 2-5). From a 1983 peak of about 441,000 students, undergraduate engineering enrollment declined to about 361,000 students by 1999, an 18 percent drop, before rebounding to 421,000 in 2002 (appendix table 2-10). Graduate engineering enrollment peaked in 1993 at 128,000, declined to 105,000 by 1999, and then rebounded past its former peak to an all-time high of 140,000 in 2002 (appendix table 2-11).

Graduate Enrollment in S&E

Advanced education in S&E toward a master's or doctoral degree prepares people for more technically oriented occupations, teaching in these fields, and research and research management positions. This section presents data on continuing key trends in graduate S&E enrollment. Information is included on patterns and trends showing how graduate students are supported during their education.

Figure 2-5
U.S. engineering enrollment, by enrollment level: 1979–2002



NOTE: Enrollment data include full- and part-time students.

SOURCE: Engineering Workforce Commission, *Engineering and Technology Enrollments, 2002–2003.* See appendix table 2-11.

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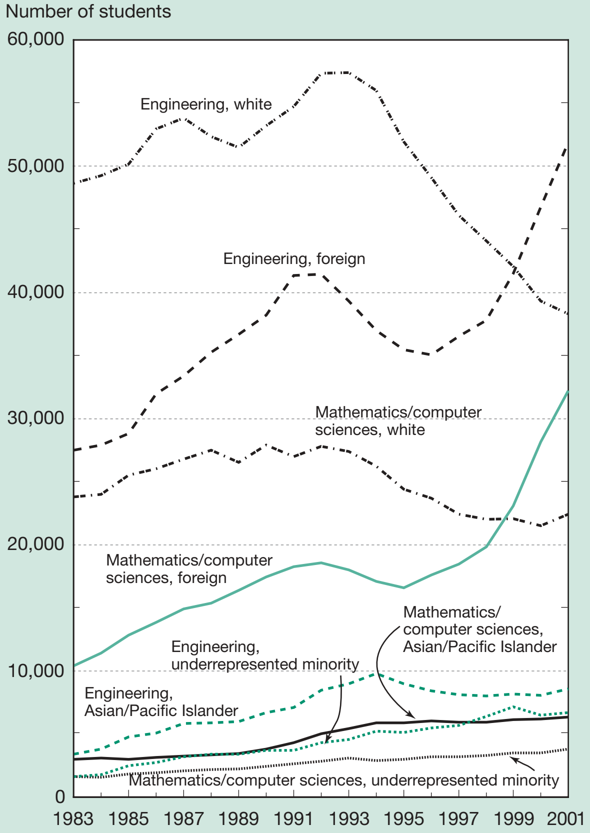
Enrollment Trends

The long-term growth trend in U.S. S&E graduate enrollment reached a peak of 435,700 in 1993. This was followed by a 5-year decline, with a recovery of growth to nearly the 1993 level by 2001. Graduate enrollment in engineering and computer sciences drove the recent growth; enrollment in most other science fields remained level or declined. By 2001, graduate enrollment in physical, earth, atmospheric, and ocean sciences had declined by 12 percent from their highs, and enrollment in mathematics declined by 17 percent. The increase in computer sciences and recent recovery in engineering mainly reflect the increasing number of foreign graduate students enrolling in these programs (figure 2-6 and appendix table 2-12).

Figure 2-6
Graduate enrollment in mathematics/computer sciences and engineering, by citizenship and race/ethnicity: 1983–2001



NOTES: Foreign citizen includes temporary residents only. Race/ethnicity groups include U.S. citizens and permanent residents. Underrepresented minority includes black, Hispanic, and American Indian/Alaskan Native.

SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-12.

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The long-term increase in overall graduate enrollment was the combined result of strong growth in foreign student enrollment (about 90 percent from 1983 to 2001), continuing increases in the number of women, and an approximate doubling in enrollment for each underrepresented minority group (appendix tables 2-12 and 2-13). These trends more than balanced a decline in the number of white men (table 2-4). Short-term trends in S&E graduate enrollment are shown in table 2-5.

The number of women enrolling in S&E graduate programs has continued to increase for the past 2 decades, except for a leveling off in psychology in the last half of the 1990s (appendix table 2-13). The long-term trend of the rising proportion of women in S&E fields also continued, but large variations among fields persisted. By 2001, women constituted most of the graduate enrollment in psychology (74 percent), biology (54 percent), and social sciences (52 percent). They constituted considerable proportions of graduate students in mathematics (38 percent) and physical, earth, atmospheric, and ocean sciences (34 percent). Women remain underrepresented in two broad fields: computer sciences (29 percent) and engineering (20 percent) (figure 2-7).

The proportion of underrepresented minority students in graduate S&E programs increased from about 6 percent in 1983 to 10 percent in 2001, well below their share in the college-age population (30 percent). However, measured as a percentage of U.S. citizens and permanent residents, their share has gone from 7 to 14 percent, approximating their share of S&E baccalaureates (16 percent). Over the period, average annual enrollment growth of underrepresented minorities was 3.9 percent, with little difference among groups; however, in the 1987–93 period, growth averaged nearly 8 percent a year, slowing to 3.4 percent annually thereafter (appendix table 2-12).

Foreign graduate student enrollment in S&E grew from 70,200 in 1983 to 133,300 in 2001, with some years of decline in the early to mid-1990s. For all S&E fields combined, the proportion of foreign students increased from 20 to 31 percent over the period (appendix table 2-12). Eight of the top 10 countries/economies of origin for foreign S&E graduate students in U.S. institutions in the 1990s were Asian, with Canada and Mexico being the exceptions (appendix table 2-14).

Over the 1983–2001 period, approximately 70 percent of the growth in the number of foreign graduate students in S&E occurred in just two fields: engineering and computer sciences. Engineering enrollment peaked in 1993, declined steeply for several years, and rebounded after 1995. Computer science enrollment rose through most of the period, with a brief drop in the mid-1990s, followed by a rapid increase (appendix table 2-12). By 2001, foreign students represented 49 percent of all graduate students in computer sciences and 47 percent in engineering. They also represented large percentages of graduate students in mathematics and physical sciences (figure 2-8).

Table 2-4
S&E graduate enrollment by citizenship and race/ethnicity: 1983–2001

Citizenship and race/ethnicity	1983	1993	2001
All S&E graduate students	346,952	435,703	429,492
U.S. citizen/permanent resident	276,749	330,037	296,194
White	224,604	256,755	205,757
Asian/Pacific Islander	9,387	24,047	27,659
Black	10,941	17,111	21,773
Hispanic	8,810	13,380	17,983
American Indian/Alaskan Native	911	1,309	1,687
Unknown race/ethnicity	22,096	17,435	21,335
Foreign citizen[a]	70,203	105,666	133,298

[a] Includes temporary residents only.

SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-12.

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Financial Support for S&E Graduate Education

U.S. higher education in S&E fields couples advanced education with research. Students' sources of financial support during graduate school can affect the character of their graduate education, including the kinds of research skills they learn, choices of research direction, and preparation for different careers. Support mechanisms include research assistantships (RAs), teaching assistantships (TAs), fellowships, and traineeships.

Sources of funding include Federal agency support, non-Federal support, and self-support. Non-Federal support includes state funds, particularly in the large public university systems; these funds are affected by the condition of overall state budgets. (See sidebar, "Definitions and Terminology of Support," for more detailed descriptions of mechanisms and sources of support.) Most graduate students, especially those who pursue doctoral degrees, are supported by more than one source and one mechanism during their time in graduate school, and some receive support from several different sources and mechanisms in a given academic year.

This section describes patterns and trends in student reliance on different mechanisms and sources of financial support.

RAs became more prominent during the latter 1980s and have accounted for 27–28 percent of total graduate support since 1988. The prevalence of traineeships and TAs declined during the 1990s; self-support reached about 33 percent during the second half of the decade (table 2-6).

In 2001, one in five graduate students received Federal financial support. This support was mostly in the form of RAs—67 percent, up from 55 percent 2 decades earlier—and was offset by declining traineeships. For students supported through non-Federal sources in 2001, TAs were the most prominent mechanism (40 percent), followed by RAs (32 percent) (appendix table 2-15).

Primary mechanisms of support differ widely by S&E field of study. For example, in 2001, students in physical sciences were supported mainly through RAs (43 percent) and TAs (39 percent). RAs were also important in engineering (42 percent). In mathematics, however, primary student support was through TAs (55 percent) and self-support (16 percent). Students in social and behavioral sciences were

Table 2-5
Change in S&E graduate enrollment, by citizenship, race/ethnicity, and sex: 1994–2001
(Percent)

Citizenship and race/ethnicity	All	Male	Female
All S&E graduate students	0	–7	12
U.S. citizen/permanent resident	–10	–19	3
White	–20	–26	–9
Asian/Pacific Islander	24	17	28
Black	24	5	39
Hispanic	35	19	56
American Indian/Alaskan Native	22	–7	28
Foreign citizen[a]	31	22	56

[a] Includes temporary residents only.

SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov.

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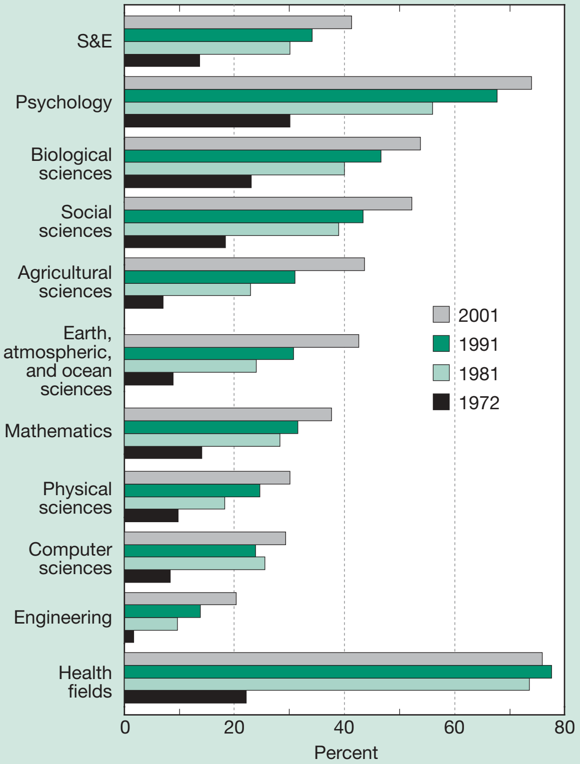
Figure 2-7
Female U.S. graduate S&E enrollment, by field: Selected years, 1972–2001



NOTE: Health fields not included in S&E total.

SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-13.

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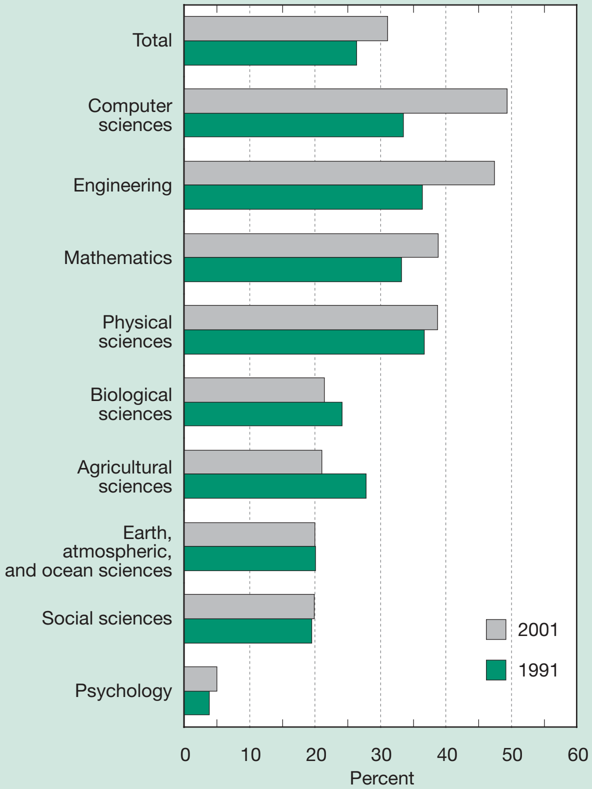
Figure 2-8
Foreign student share of U.S. graduate S&E enrollment, by field: 1991 and 2001



SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-12.

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Definitions and Terminology of Support

Mechanisms of support: These may come from Federal or non-Federal sources.

Research assistantships (RAs) are given to students whose assigned duties are devoted primarily to research.

Teaching assistantships (TAs) are given to students whose assigned duties are devoted primarily to teaching.

Fellowships are competitive awards (often from a national competition) given to students for financial support of their graduate studies.

Traineeships are educational awards given to students selected by the institution.

Other mechanisms of support include work-study programs, business or employer support, and support from foreign governments other than a previously mentioned mechanism.

Sources of support: Except for self-support, funds may take the form of any mechanism; institutional support may take the form of tuition remission.

Federal support is provided by Federal agencies, chiefly in the form of RAs and traineeships; it also includes items such as tuition paid by the Department of Defense for members of the Armed Forces.

Non-Federal support is provided by the institution of higher education, state and local governments, foreign sources, nonprofit institutions, or private industry.

Self-support is derived from any loans obtained (including Federal loans) or from personal or family contributions.

Table 2-6
Support mechanisms of full-time S&E graduate students: 1980–2001
(Percent distribution)

Year	All mechanisms	Research assistantship	Fellowship	Traineeship	Teaching assistantship	Other	Self-support
1980	100.0	21.6	8.6	7.4	22.6	8.2	31.6
1983	100.0	21.8	8.5	5.4	23.8	8.3	32.2
1986	100.0	24.8	8.6	5.1	23.5	8.4	29.6
1989	100.0	28.0	8.3	5.1	22.7	7.5	28.4
1992	100.0	27.3	8.9	4.8	20.4	7.3	31.4
1995	100.0	27.3	8.8	4.8	20.0	6.6	32.4
1998	100.0	26.9	8.9	4.6	19.9	6.7	33.1
2001	100.0	28.1	9.1	4.0	19.1	6.7	33.0

SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-15.

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mainly self-supporting (43 percent) or received TAs (20 percent) (appendix table 2-16).

The Federal Government plays a significant role in supporting S&E graduate students in some mechanisms and fields and a small role in others. For example, in 2001, the Federal Government sponsored 59 percent of S&E traineeships, 47 percent of RAs, and 22 percent of fellowships.[7] Federal support reaches relatively large proportions of students in physical, earth, atmospheric, ocean, and life sciences and engineering. However, few students receive Federal support in mathematics, computer sciences, social sciences, and psychology (figure 2-9). Appendix table 2-17 gives detailed information by field and mechanism.

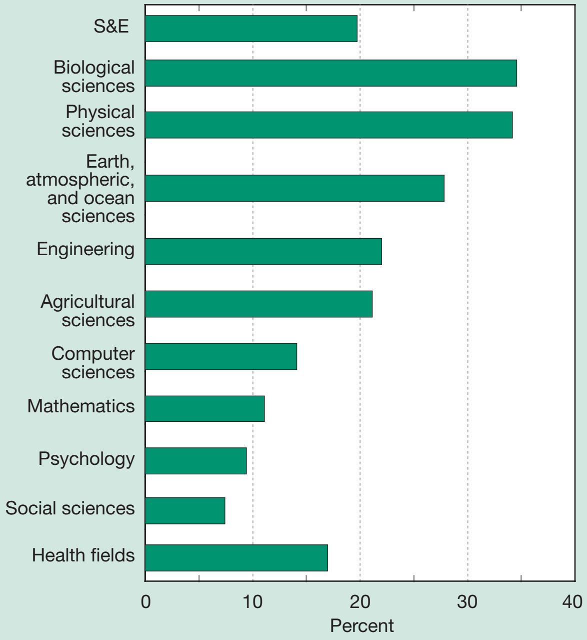
The National Institutes of Health (NIH) and NSF support most of the S&E graduate students whose primary support comes from the Federal Government. In 2001, they supported about 20,000 and 15,000 students, respectively. Two-decade trends in Federal agency support of graduate students showed considerable increases in the proportion of students funded (NIH, from 22 to 29 percent; NSF, from 18 to 23 percent). Support from the Department of Defense declined during the 1990s (appendix table 2-18).

For doctoral degree students, notable differences exist in primary support mechanisms by sex, race/ethnicity, and citizenship. In 2001, men were most likely to be supported by RAs (30 percent), and women were most likely to support themselves from personal sources of funds (34 percent). Whites and Asian/Pacific Islanders were most likely to derive primary support from RAs (26 and 31 percent, respectively), and underrepresented minorities depended more on fellowships (36 percent). The primary source of support for foreign doctoral degree students was an RA (table 2-7).

Higher Education Degrees

Degree conferral represents the certification of achievement at various levels of education and training. Over the years, U.S. colleges and universities have awarded rising numbers of associate's, bachelor's, master's, and doctoral degrees in all fields. The number of degrees in S&E fields has generally risen along with other fields.

Figure 2-9
Full-time S&E graduate students with primary support from Federal Government, by field: 2001



NOTE: Health fields not included in S&E total.

SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-17.

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[7] Federal fellowships and traineeships are available only to U.S. citizens and permanent residents; however, this does not apply to Federal research assistantships.

Table 2-7
Selected primary mechanisms of support for S&E doctorate recipients, by citizenship, sex, and race/ethnicity: 2001
(Percent distribution)

Citizenship, sex, and race/ethnicity	All mechanisms	Research assistantship	Fellowship	Teaching assistantship	Other	Personal
U.S. citizen	100.0	25.4	23.5	14.9	11.7	24.5
Male	100.0	29.9	23.0	15.7	11.8	19.5
Female	100.0	19.8	24.1	13.8	11.6	30.8
White	100.0	26.2	21.3	15.9	11.3	25.2
Asian/Pacific Islander	100.0	31.4	30.0	10.9	13.3	14.3
Underrepresented minority	100.0	13.5	37.8	9.8	12.4	26.4
Temporary resident	100.0	46.0	15.9	17.0	15.0	6.1

SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-19.

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S&E Associate's Degrees

Associate's degrees, largely offered by 2-year programs at community colleges, offer basic technical certification, primarily in computer and social science, engineering, and technology fields. S&E associate's degrees rose from 26,500 in 1985 to 33,700 in 2000. The increase in the late 1990s was mainly attributed to computer sciences, which represented 56 percent of all S&E associate's degrees by 2000. In contrast, the number of associate's degrees in natural sciences and engineering decreased in the late 1990s. Degrees earned in engineering technologies (not included in S&E totals because of their practice-focused nature) remained more numerous than degrees in S&E fields but experienced a steady decline during the past 2 decades (appendix table 2-20).

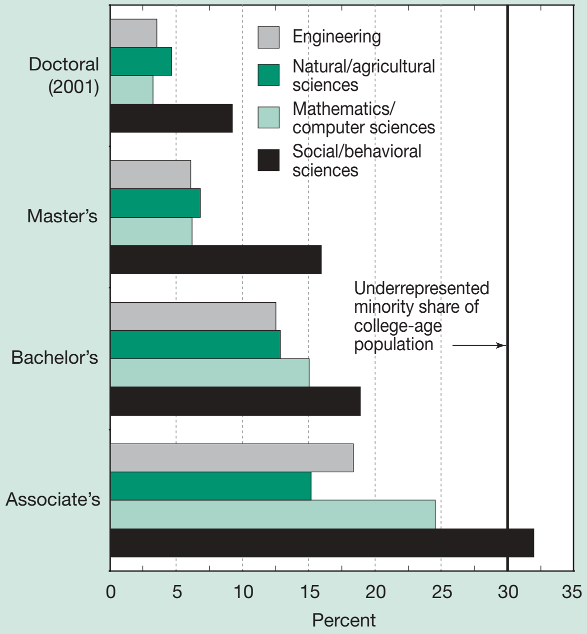
Race/ethnicity trends in the number of associate's degrees earned are shown in appendix table 2-21. Students from underrepresented groups earn a considerably higher proportion of associate's degrees than of bachelor's or more advanced degrees. In 2000, their proportion of associate's degrees was 32 percent for social and behavioral sciences and about 25 percent for mathematics and computer sciences (figure 2-10). The proportion of computer science degrees earned by these students has almost doubled since 1985.

S&E Bachelor's Degrees

The ratio of bachelor's degrees to the size of the college-age cohort (24-year-olds are a proxy) is a useful indicator of educational achievement. This ratio has risen from 21.8 per 100 in 1980 to 33.8 per 100 in 2000. The ratio of bachelor's degrees in natural, agricultural, and computer sciences; mathematics; and engineering (NS&E) to the population cohort stood between 4 and 5 per 100 for several decades but increased to 5.7 in the late 1990s, largely on the strength of increases in computer science baccalaureates (National Science Board 2002 and table 2-8).

The annual output of S&E bachelor's degrees rose steadily from 303,800 in 1977 to about 398,600 in 2000; they represented approximately one-third of baccalaureates over the entire period. However, these consistent trends mask considerable variations among fields (figure 2-11). The number of earned degrees in engineering and computer sciences grew sharply in the early 1980s, peaked in 1986, and then dropped precipitously before leveling off in the 1990s. In the 1990s, degrees in biological and agricultural sciences and psychology began a steady increase. By 1992,

Figure 2-10
Underrepresented minority share of S&E degrees, by degree level and field: 2000 or 2001



NOTES: Natural sciences include physical, biological, earth, atmospheric, and ocean sciences. Underrepresented minority includes black, Hispanic, and American Indian/Alaskan Native.

SOURCES: U.S. Department of Education, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix tables 2-21, 2-23, 2-25, and 2-27.

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Table 2-8
Ratio of bachelor's degrees to the 24-year-old population, by selected fields, sex, and race/ethnicity: 1990 and 2000

	Degree					Degree		
Sex and race/ethnicity	All bachelor's degrees	All S&E	NS&E	Social/ behavioral sciences	24-year-old population	Bachelor's	NS&E[a]	Social/ behavioral science
	Number					Ratio to 24-year-old population[b]		
1990 total	1,062,160	345,794	169,938	175,856	3,722,737	28.5	4.6	4.7
Male	495,876	199,917	117,249	82,668	1,855,513	26.7	6.3	4.5
Female	566,284	145,877	52,689	93,188	1,867,224	30.3	2.8	5.0
White	856,686	270,225	127,704	142,521	2,628,439	32.6	4.9	5.4
Asian/Pacific Islander	38,027	19,437	13,338	6,099	120,797	31.5	11.0	5.0
Underrepresented minority	107,377	33,419	15,259	18,160	973,500	11.0	1.6	1.9
Black	59,301	18,230	7,854	10,376	484,754	12.2	1.6	2.1
Hispanic	43,864	13,918	6,868	7,050	459,073	9.6	1.5	1.5
American Indian/Alaskan Native	4,212	1,271	537	734	29,674	14.2	1.8	2.5
2000 total	1,253,121	398,622	210,434	188,188	3,703,200	33.8	5.7	5.1
Male	536,158	197,669	128,111	69,558	1,886,400	28.4	6.8	3.7
Female	716,963	200,953	82,323	118,630	1,816,800	39.5	4.5	6.5
White	895,129	270,416	142,400	128,016	2,433,400	36.8	5.9	5.3
Asian/Pacific Islander	75,265	12,368	23,185	12,368	148,800	50.6	15.6	8.3
Underrepresented minority	200,967	63,519	27,939	35,559	1,121,000	17.9	2.5	3.2
Black	104,212	32,924	13,795	19,129	527,600	19.8	2.6	3.6
Hispanic	88,324	27,984	12,919	15,065	560,200	15.8	2.3	2.7
American Indian/Alaskan Native	8,431	2,611	1,246	1,365	33,200	25.4	3.8	4.1

NS&E natural sciences and engineering

[a] NS&E degrees include natural (physical, biological, earth, atmospheric, and ocean sciences), agricultural, and computer sciences; mathematics; and engineering.
[b] Number of degrees per 100 24-year-olds.

NOTE: Degrees by race/ethnicity do not sum to total because data not shown for unknown race/ethnicity or foreign citizens.

SOURCES: U.S. Department of Education, Completions Survey; National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov; and U.S. Bureau of the Census, Population Division. See appendix tables 2-4, 2-22, and 2-23.

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the number of psychology degrees surpassed the number earned in engineering, and, in 1997, biological and agricultural sciences surpassed engineering as well. After 1997, degrees in engineering began to decline further, but those in computer sciences increased sharply, almost reaching their mid-1980s level by 2000 (appendix table 2-22).

Trends in earned degrees in broad fields can mask differences among subfields. For example, within the decline in physical sciences in the 1990s, degrees in chemistry actually increased. Similarly, declines in social sciences masked divergent trends; degrees in sociology continued to increase, whereas those in economics declined from their peak in the early 1990s (NSF/SRS 2002).

Innovations in Undergraduate S&E Education

Concerns about the growing need for scientifically trained workers and scientifically literate citizens have prompted the higher education community to examine the quality of the undergraduate experience and explore new approaches. Several recent studies called for reform (Association of American Colleges and Universities 2002; National Research Council 2002, 2003a, and 2003b; and Project Kaleidoscope 2002). These studies have common themes, including urging S&E educators to move toward more interdisciplinary education and more fully incorporate mathematical approaches; giving students experience in retrieving and manipulating large databases; exploring the use of electronic delivery; involving students in dialogue about their study topics; and providing research experiences early in students' academic careers, both in regular classroom settings and as part of a research team external to the classroom laboratory. The sidebar "Bioinformatics" describes how these changes are being manifested in life sciences.

Innovations are also under way to improve teaching, both at the undergraduate level and in K–12. Science funding agencies and professional societies support faculty to design, test, and improve computer-driven classes. The Federal Government has developed repositories of teaching materials, such as the Department of Education's Eisenhower National Clearinghouse for Mathematics and Science Education and NSF's National Science, Technology, Engineering and Mathematics Education Digital Library. Programs that recognize and reward outstanding teachers and scholars highlight the value of integrating research and education during the undergraduate years.[8] Other programs recognize

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[8] For example, the NSF Director's Award for Distinguished Teaching Scholars and the Howard Hughes Medical Institute Award, which further the participation of forefront S&E faculty in undergraduate education at research universities.

mentoring efforts that have increased the participation of women and underrepresented minorities in S&E.[9]

The need to improve K–12 teacher preparation in S&E has been widely noted (see chapter 1 and National Commission on Mathematics and Science Teaching for the 21st Century 2000). The Presidential Award for Excellence in Mathematics and Science Teaching was established in 1983 to recognize outstanding teachers from each state. More recently, the Math and Science Partnership program, initiated in 2002, is designing ways to link institutions of higher education and local school districts to improve student achievement and teacher training. The sidebar "Meeting the Challenge of Teacher Preparation" notes some initial results of various programs that are under way to foster collaboration between S&E faculty and schools of education to improve teacher preparation. These efforts, although promising, are unlikely to solve this national need alone.

S&E Bachelor's Degrees by Sex

Women have outnumbered men in undergraduate education for several decades and earned 57 percent of all bachelor's degrees in 2000. Because men are more likely to choose S&E majors, however, they earned half of the total S&E bachelor's degrees in that year. About 37 percent of the bachelor's degrees earned by men were in S&E fields, compared with 28 percent for women. The female share was a slight increase from 25 percent in the late 1970s; the male share was a decline from 40 percent.

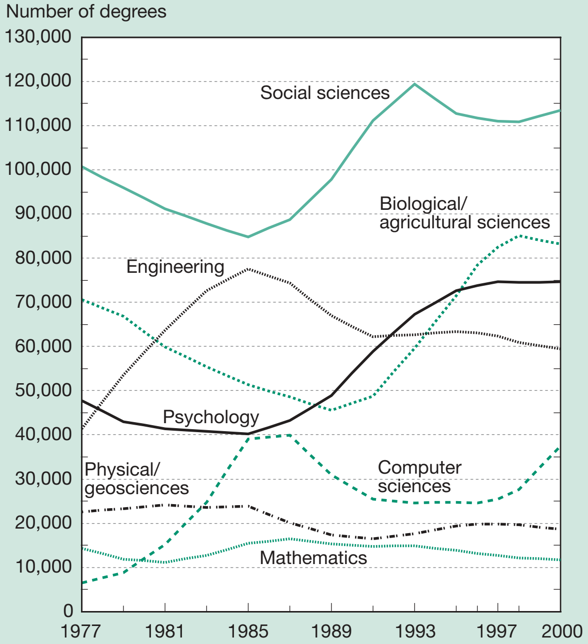
Within S&E, men and women tend to study different fields. Men earned most of the bachelor's degrees in engineering, computer science, and physical science fields (79, 72, and 59 percent, respectively). Women earned 77 percent of the bachelor's degrees in psychology, 59 percent in biological sciences, 54 percent in social sciences, and 48 percent in mathematics (appendix table 2-22 and figure 2-12).

S&E Bachelor's Degrees by Race/Ethnicity

In the past 2 decades, the racial/ethnic composition of those earning S&E bachelor's degrees changed, reflecting both population growth and increasing college attendance by members of minority groups. Between 1977 and 2000, the proportion of S&E degrees awarded to Asian/Pacific Islanders increased from 2 to 9 percent, and the proportion awarded to members of underrepresented minority groups grew from 9 to 16 percent (figure 2-13). In contrast, the proportion of S&E bachelor's degrees earned by white students declined from 87 percent in 1977 to 68 percent in 2000.[10] During the 1990s, the number of degrees earned by white students decreased in all S&E fields except computer, biological, and agricultural sciences and psychology.

In the 1990s, race/ethnicity trends in degrees earned differed by S&E field. American Asian/Pacific Islanders increased their share of degrees in all S&E fields (except

Figure 2-11
S&E bachelor's degrees, by field: Selected years, 1977–2000



NOTE: Geosciences include earth, atmospheric, and ocean sciences.

SOURCES: U.S. Department of Education, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-22.

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Bioinformatics

Changes under way in S&E education are readily apparent in bioinformatics. This field is increasingly interdisciplinary, as emerging technologies increase the amount of information that faculty and students across disciplines can gather, analyze, manipulate, and present.

In bioinformatics, powerful research resources are being accessed and used by undergraduate students and by researchers at the frontiers of their fields. The bioinformatics community offers Web-based material that students can access and manipulate. RasMol (http://www.umass.edu/microbio/rasmol), one of the most popular sites, has been accessed by more than 500,000 people in 115 countries. The Biology Workbench (http://workbench.sdsc.edu) contains information for both faculty and students and has held workshops to help people adapt their materials. A newly established resource in bioinformatics, aimed specifically at 2-year college users, illustrates how research at a commercial company, Geospiza, can serve as a base for education projects (http://www.geospiza.com/outreach/index).

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[9] For example, the Presidential Awards for Excellence in Science, Mathematics and Engineering Mentoring.

[10] Because of omission of an other or unknown race/ethnicity category, these percentages do not total 100 percent; see appendix table 2-23.

Meeting the Challenge of Teacher Preparation

Teacher preparation remains a responsibility of institutions of higher education, and some S&E faculty are becoming more involved in strengthening K–12 teacher preparation. A few of the innovative programs are described below. However, to keep pace with the increasing need for highly qualified teachers of science and mathematics, institutions of higher education would need to engage more S&E faculty in high-quality teacher preparation.

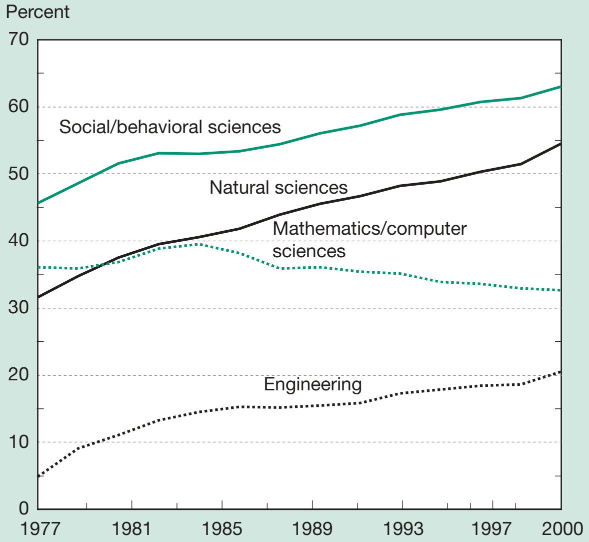
The National Science Foundation's Collaboratives for Excellence in Teacher Preparation program has stimulated reform of teacher preparation in 250 institutions of higher education, including 102 community colleges, through the collaborative efforts of more than 3,000 S&E and education faculty. More than 1,000 undergraduate courses have been revised or developed to improve the preparation of future teachers of science and mathematics by reflecting best practices in teaching.

RECRUIT is a program for recruiting, educating, certifying, and retaining underrepresented populations in teaching science and mathematics. The program prepares S&E graduates and midcareer scientists, mathematicians, and industry personnel for teaching careers in middle and high schools. Through collaboration among education faculty, S&E faculty, and K–12 teachers, the project provides an extended induction, support, and professional development period that continues 2 years beyond the initial 1-year training. Novice teachers participate in seminars taught by S&E and education faculty and receive support from mentor teachers. RECRUIT teachers are expected to affect 4,500 middle and high school students.

Enlist, Equip, and Empower (E^3) at Western Michigan University is designed to address the unique needs of middle school teachers for a conceptual understanding of general science principles across many disciplines. The project joins a science faculty member, science education faculty member, and middle school science teacher to work on improving the science knowledge and pedagogy of future middle school teachers.

mathematics), particularly computer, biological, and physical sciences and engineering. Blacks had slight increases in overall S&E degrees in the past 2 decades but had the strongest growth in biological and computer sciences, psychology, and engineering technologies. Hispanics had strong increases (but from a low base), especially in computer and biological sciences and psychology. American Indian/Alaskan Natives earned an increasing number of S&E degrees, but their total number of S&E bachelor's degrees in 2000 barely exceeded 2,600 (appendix table 2-23).

Figure 2-12
Female share of S&E bachelor's degrees, by selected fields: Selected years, 1977–2000



NOTES: Data for 1983 are estimated. Natural sciences include physical, biological, earth, atmospheric, and ocean sciences.

SOURCES: U.S. Department of Education, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-22.

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Despite considerable progress for underrepresented minority groups between 1990 and 2000 in earning bachelor's degrees, the gap in educational attainment between minorities and whites continues to be wide, especially in S&E fields. In 2000, the ratio of college degrees earned by members of these groups was 17.9 per 100 24-year-olds, about half that of whites. Their ratio for NS&E degrees was even lower (table 2-8). In contrast, Asian/Pacific Islanders have considerably higher-than-average achievement: 50.6 bachelor's degrees per 100 college-age population and 15.6 NS&E degrees per 100 college-age population in 2000.

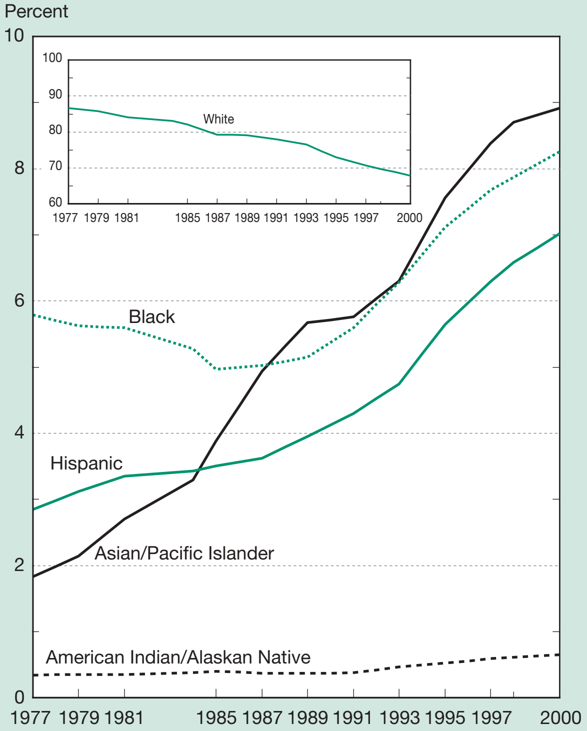
Bachelor's Degrees by Citizenship

Foreign students in the United States earned a small share (3.8 percent) of S&E degrees at the bachelor's level (appendix table 2-23). Trends in degrees earned by foreign students in the 1990s showed increases in the number of bachelor's degrees in social sciences and psychology, fluctuating and declining numbers in physical sciences and engineering, and relatively stable numbers in computer sciences, with an upturn in 2000. Foreign students in U.S. institutions earned approximately 7–8 percent of bachelor's degrees awarded in computer sciences and engineering (appendix table 2-23).

S&E Master's Degrees

Master's degrees in S&E fields increased from 63,800 in 1977 to 95,700 in 2000. The long-term growth peaked in 1995, then leveled off (except in computer sciences), and

Figure 2-13
Minority share of S&E bachelor's degrees, by race/ethnicity: Selected years, 1977–2000



SOURCES: U.S. Department of Education, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-23.

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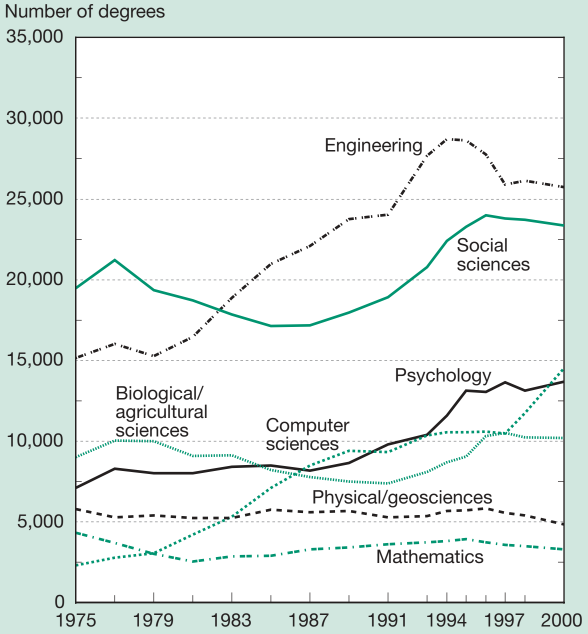
rose again in 2000. The four most common major fields accounted for most of the growth: engineering, social sciences, computer sciences, and psychology (figure 2-14). The mid-1990s decline in engineering master's degrees reflected enrollment declines for foreign students.

Research and doctorate-granting universities produced most of the master's degrees earned in engineering (87 percent), natural sciences (77 percent), and mathematics and computer sciences (68 percent) (figure 2-15).

Master's Degrees by Sex

Since 1975, the number of S&E master's degrees earned by women has tripled, rising from 13,800 to 41,500 in 2000 (figure 2-16). In addition to earning increasing numbers of degrees in both social sciences and psychology, which have historically had strong female representation, women showed strong growth in engineering and computer sciences (appendix table 2-24). In contrast, the number of master's degrees that men earned grew only marginally, from 49,400 in 1975 to 54,200 in 2000. The most popular S&E master's degrees for men remain in engineering, social sciences, and computer sciences.

Figure 2-14
S&E master's degrees, by field: Selected years, 1975–2000



NOTE: Geosciences include earth, atmospheric, and ocean sciences.

SOURCES: U.S. Department of Education, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-24.

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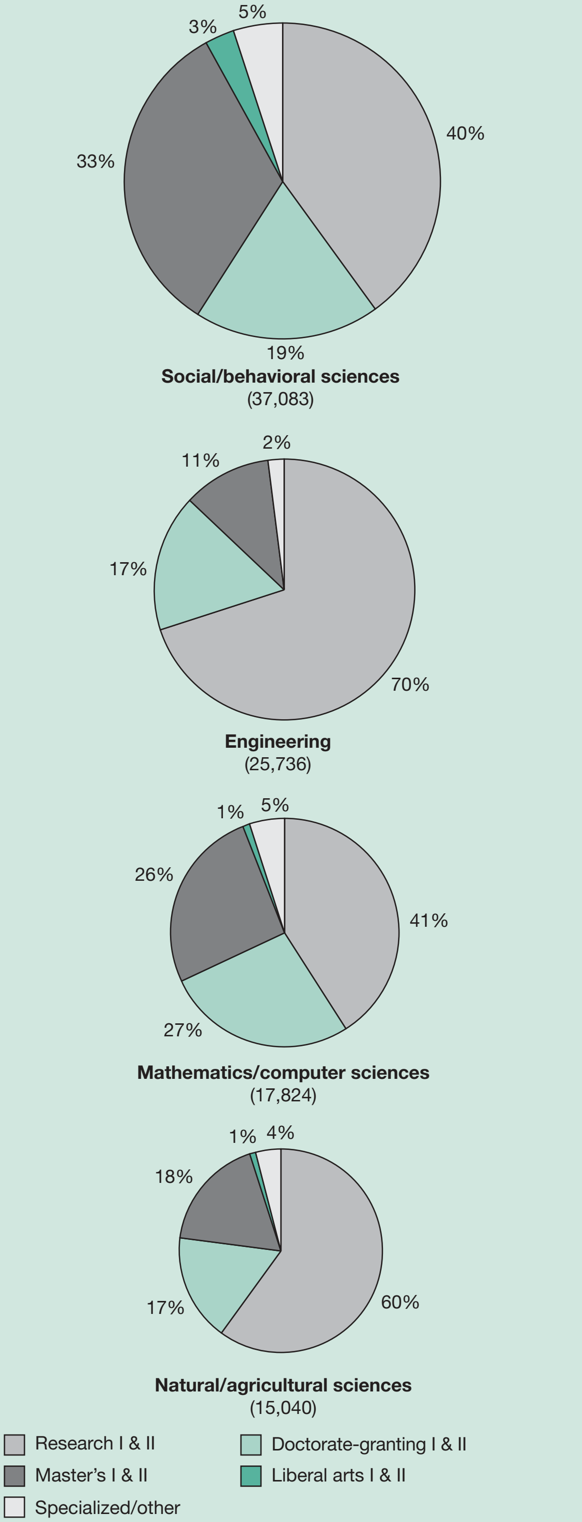
Master's Degrees by Race/Ethnicity

The proportion of S&E master's degrees earned by U.S. racial/ethnic minorities increased over the past 2 decades. Asian/Pacific Islanders accounted for 7.3 percent of master's degrees in 2000, up from 2.7 percent in 1977. Underrepresented minorities also registered gains, increasing from 5.9 to 10.1 percent during this period. The largest gains for underrepresented minorities were in engineering and physical sciences, both of which started from a very low base. Their percentage of master's degrees in engineering increased from 3.2 percent in 1977 to 6.1 percent in 2000; the corresponding figures in physical sciences were 3.4 and 6.3 percent (appendix table 2-25).

Master's Degrees by Citizenship

S&E master's degrees increased more rapidly among foreign students than among underrepresented minority groups or all U.S. citizens (figure 2-17), going from 7,800 in 1977 to 24,800 in 2000 (appendix table 2-25). This pushed their share of these degrees from 12 to 26 percent over this period. Foreign students make up a much higher proportion of S&E degree recipients at the master's level than at lower levels of the system. Their degrees are heavily concentrated in computer sciences (representing 45 percent of master's degrees awarded in that field) and engineering (38 percent of engineering degrees awarded) (appendix table 2-25). The increases among

Figure 2-15
S&E master's degrees, by field and institution type: 2000



NOTES: Natural sciences include physical, biological, earth, atmospheric, and ocean sciences. Number of degrees in parentheses.

SOURCES: U.S. Department of Education, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-3.

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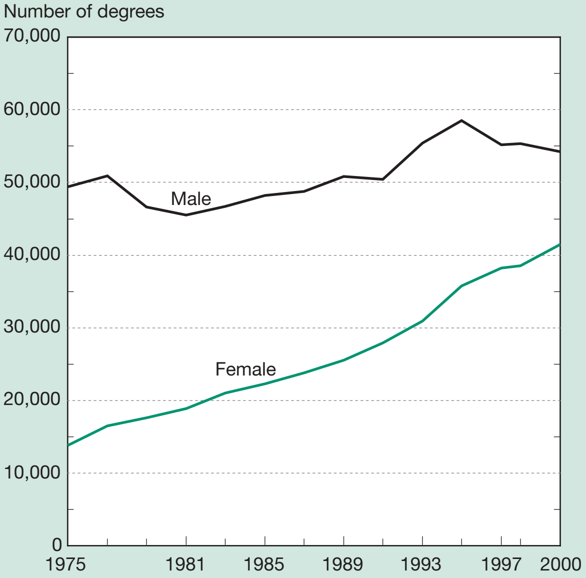
Figure 2-16
S&E master's degrees, by sex: Selected years, 1975–2000



SOURCES: U.S. Department of Education, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-24.

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minorities and foreign students, along with a decline in the number of U.S. white students, led to a fall in the white majority share of S&E master's degrees from 79 percent in 1977 to 52 percent in 2000 (figure 2-18 and appendix table 2-25).[11]

New Directions in Master's Programs

Many institutions are revisiting the graduate education programs they offer, perhaps in response to the suggestions of the Committee on Science, Engineering, and Public Policy (COSEPUP 1995) report to better prepare students for professional opportunities beyond research or to the uneven value the degree is accorded in different S&E fields. Although a master's degree in engineering is highly valued and an increasingly popular degree in the United States and other countries, a master's degree in some science fields implies a lack of advancement to the doctoral level.

Discussions in recent years have focused on creation of degree programs that validate useful advanced training below the doctoral level. These discussions have led to new directions in graduate education, manifested in new types of master's degree programs and the proliferation of professional certificate programs. The new master's programs often stress interdisciplinary training for work in emerging S&E fields. (See sidebar, "Developments in Master's Degree Programs.") Professional certificate programs at the graduate level are typically amenable to distance delivery

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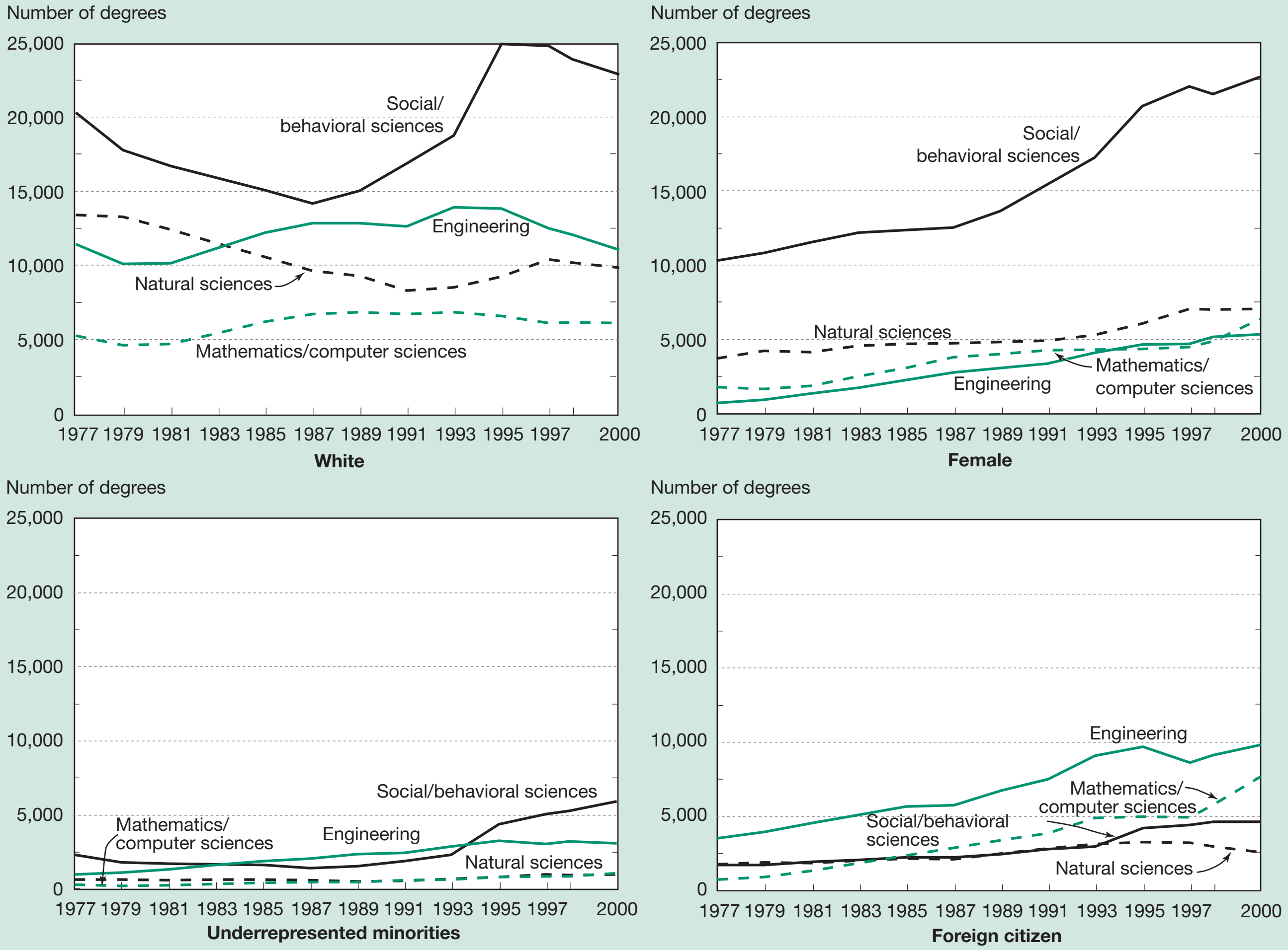
[11] An increase of 4 percentage points also occurred in the number of degree recipients with other or unknown race/ethnicity.

Figure 2-17
Master's degrees in S&E fields earned by selected groups: 1977–2000



NOTES: Data are estimated for 1983. Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences. Underrepresented minorities include black, Hispanic, and American Indian/Alaskan Native. White and underrepresented minorities include U.S. citizens and permanent residents. Foreign citizen includes temporary residents.

SOURCES: U.S. Department of Education, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix tables 2-24 and 2-25.

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at corporate sites. These programs include a coherent set of courses for a specialty, such as engineering management.

S&E Doctoral Degrees

America's leaders in S&E research and education, especially in the academic sector, are drawn heavily from doctorate holders. As occurs at the bachelor's and master's degree levels, trends toward increasing numbers of S&E degree recipients and increasing the proportion of women, minorities, and foreign students occur at the doctoral level.

The number of S&E doctorates conferred annually by U.S. universities fluctuated around 18,000–19,000 through the mid-1980s, reached a peak of 28,800 in 1998, and declined to 27,100 in 2001. The rise through 1998 largely reflected growth in the number of foreign U.S. degree recipients. The largest degree increases were in engineering, biological sciences, and, to a lesser extent, social and computer sciences (figure 2-19). The post-1998 decline in earned doctorates reflects fewer degrees earned by both U.S. citizens and permanent residents (see "Doctoral Degrees by Citizenship").

Doctoral Degrees by Sex

Among U.S. citizens, the proportion of S&E doctoral degrees earned by women has risen considerably in the past 3 decades, reaching a record 44 percent in 2001 (appendix table 2-26). Over this period, women made strong and uninterrupted gains, albeit from different bases, in all major field groups. However, as figure 2-20 shows, among total doctoral recipients, considerable differences by field continue, and the long-term trend of an increasing number of doctoral degrees earned by women may have begun to level off in 1999.

Developments in Master's Degree Programs

Attempts have recently been made to offer master's-level science education tailored to students interested in various nonacademic career options. These programs prepare students for positions in management, new product development, or consulting in the business, government, or nonprofit sectors. Many programs offer industrial internships or have courses with significant industry involvement, thereby building relationships between a university and the corporate sector. Some programs, such as the Master of Science in Financial Mathematics program at the University of Chicago, have been in existence for years, whereas others are new (Simmons 2003).

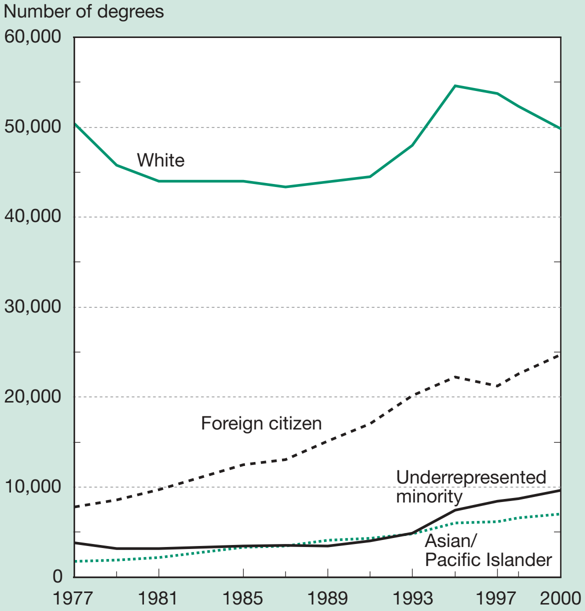
The Alfred P. Sloan Foundation is a primary sponsor of the current initiative in professional master's degree programs. By 2003, the Sloan Foundation will have funded 83 degree-granting programs at 35 research universities and 10 master's-focused institutions in fields from bioinformatics and computational linguistics to zoo and aquarium science management (http://www.sciencemasters.com). In fall 2002, 631 students were enrolled in Sloan Foundation-funded programs, with female students comprising 33 percent and underrepresented minority students comprising 8 percent of the student body.

Doctoral Degrees by Race/Ethnicity

Although the proportion of S&E doctoral degrees earned by U.S. majority whites decreased in the past 2 decades, their number of S&E doctorates remained relatively stable, fluctuating between about 12,600 and 14,500 degrees annually. S&E doctoral degrees earned by whites reached 14,700 in 1995 and declined slightly each year since then, mainly in engineering, mathematics, and computer sciences (appendix table 2-27). The slight drop in these degrees may reflect good employment opportunities in high-technology industries during this period. The share of all S&E doctoral degrees earned by white U.S. citizens and permanent residents decreased from 71 percent in 1977 to 50 percent in 2001. As a share of S&E degrees awarded to U.S. citizens and permanent residents, it declined from 86 to 78 percent.

The proportion of doctoral degrees in S&E fields earned by U.S. underrepresented minorities increased slowly over the past 2 decades. Underrepresented minorities earned almost 1,550 S&E doctorates in 2001, accounting for 5.7 percent of the S&E doctoral degrees that year, up from 3.3 percent in 1977 (figure 2-21). Their share of degrees earned by U.S. citizens and permanent residents rose from 4 to 9 percent over the period. Gains by all underrepresented groups contributed to this rise; the number of degrees earned by blacks doubled, by Hispanics more than tripled, and by American Indian/Alaskan Natives nearly tripled. However, all three groups showed declines after 1999 or 2000.

Figure 2-18
S&E master's degrees, by race/ethnicity and citizenship: Selected years, 1977–2000



NOTES: Race/ethnicity groups include U.S. citizens and permanent residents. Underrepresented minority includes black, Hispanic, and American Indian/Alaskan Native. Foreign citizens include temporary residents only.

SOURCES: U.S. Department of Education, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-25.

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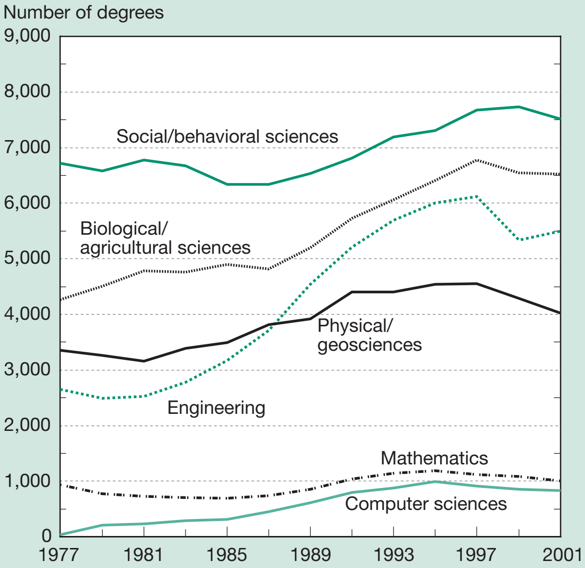
Figure 2-19
S&E doctoral degrees earned in U.S. universities, by field: 1977–2001



NOTE: Geosciences include earth, atmospheric, and ocean sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-26.

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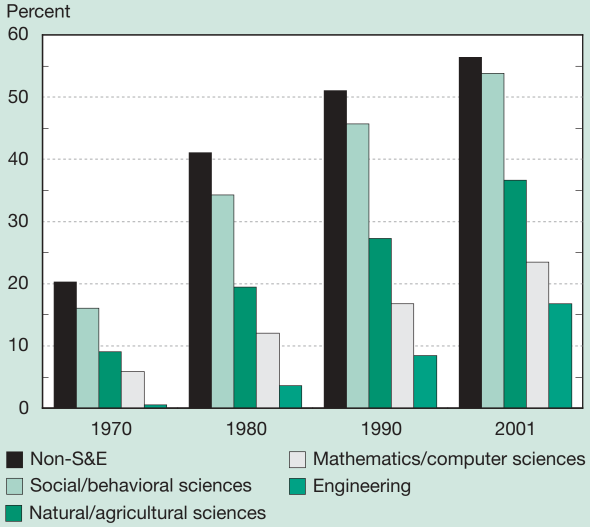
Figure 2-20
Doctoral degrees earned by women in U.S. institutions, by field: Selected years, 1970–2001



NOTE: Natural sciences include physical, biological, earth, atmospheric, and ocean sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-26.

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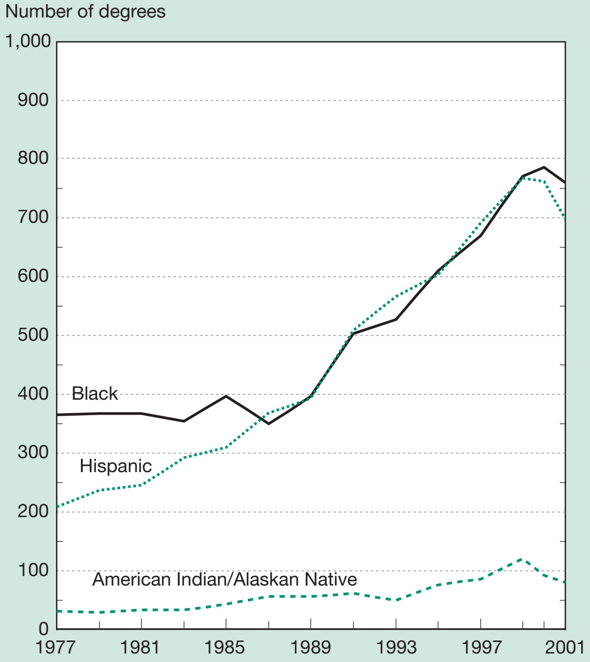
Figure 2-21
Underrepresented minority S&E doctoral degrees, by race/ethnicity: Selected years, 1977–2001



SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-27.

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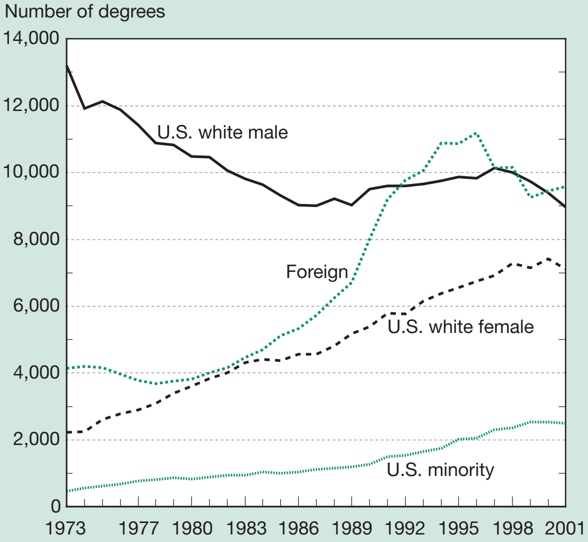
The largest gains were in social sciences and psychology. By 2001, the percentage of doctoral degrees earned by underrepresented minorities in psychology reached 11 percent, up from 5 percent in 1977; doctorates in social sciences increased from 5 percent in 1977 to 8 percent in 2001. Their number of engineering and computer science doctorates increased modestly throughout the 1990s but have decreased from highs reached in the late 1990s.

In the mid-1990s, doctoral degrees earned by Asian/Pacific Islanders who were citizens and permanent residents showed a steep increase. This increase mainly reflects the many Chinese doctoral students on temporary visas who shifted to permanent-resident status as a result of the 1992 Chinese Student Protection Act. The number of degrees earned by Asian/Pacific Islanders has since declined, representing a little more than 6 percent of the total in 2001.

Doctoral Degrees by Citizenship

Noncitizens account for most of the growth in U.S. S&E doctorates from the late 1980s through 2001 (figure 2-22). The number of degrees earned by U.S. citizens rose from 13,700 in 1985 to 17,300 in 1998 and then declined to 16,100 in 2001; non-U.S.-citizen degrees rose from 5,100 to 9,600 over the period, pushing the foreign share upward from about 26 to 35 percent by 2001. The number of S&E doctorates awarded to noncitizens peaked in 1996, leveled off and declined until 1999, and then began rising again. During the 1985–2001 period, foreign students at U.S. universities

Figure 2-22
U.S. S&E doctoral degrees, by sex, race/ethnicity, and citizenship status: 1973–2001



NOTES: Foreign includes permanent and temporary residents. Minority includes Asian/Pacific Islander, black, Hispanic, and American Indian/Alaskan Native. Degree recipients with unknown citizenship are omitted.

SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix tables 2-26, 2-27, and 2-28.

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earned close to 148,000 U.S. doctoral degrees in S&E fields (appendix table 2-28).

Foreign students earned a larger proportion of degrees at the doctoral level than at any other degree level, more than one-third of all S&E doctoral degrees awarded. Their proportion in some fields was considerably higher: in 2001, foreign students earned 49 percent of doctoral degrees in mathematics and computer sciences and 56 percent in engineering (figure 2-23). In particular subfields, foreign doctoral recipients were an even higher proportion of the total (e.g., 65 percent in electrical engineering) (NSF/SRS 2003b).

Doctoral Degrees by Time to Degree

Completing an S&E doctorate takes a long time, and time spent in school usually involves at least a short-term financial sacrifice. The time required to earn a degree affects the attractiveness of undertaking and persisting in doctoral study, which may, in turn, affect the number of doctorates and the quality of doctoral students.

The NSF Survey of Earned Doctorates tracks patterns and trends in the time it takes to earn an S&E doctorate. The survey measures time to degree in several ways. This section contains information about the median number of years between baccalaureate receipt and doctorate receipt and while registered in graduate school before doctorate completion (appendix table 2-29).

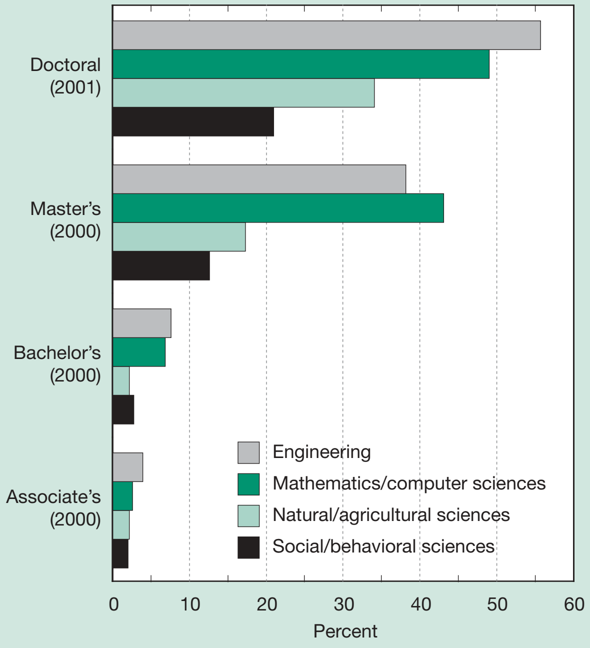
Data on the time from baccalaureate to doctorate show increases for all fields until the mid-1990s, followed by decreases thereafter. Physical sciences had the shortest and social sciences the longest time to degree. In the mid-1990s, the median time to degree completion was nearly 8 years in physical sciences, almost 9 years in engineering and biological sciences, and around 11 years in social sciences. By 2001, time to degree in each of these fields (as measured by elapsed time from baccalaureate) had shortened considerably (figure 2-24 and appendix table 2-29).

In registered time to degree, an increase occurred for all fields over time and persisted through the mid-1990s to 2000, with a slight shortening in several fields in 2001. Among S&E fields, in 2001, registered time to degree was shortest in physical sciences (6.4 years) and engineering (6.7 years) and longest in social sciences (8.2 years).

Postdocs

During the 1990s, increasing numbers of new doctorate holders received appointments as postdoctoral fellows. These positions were originally conceived as temporary appointments to obtain further specialized training after

Figure 2-23
Foreign student share of S&E degrees, by degree level and field: 2000 or 2001



NOTES: At the doctoral level, foreign students include permanent and temporary residents; other levels include only temporary residents. Natural sciences include physical, biological, earth, atmospheric, and ocean sciences.

SOURCES: U.S. Department of Education, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix tables 2-21, 2-23, 2-25, and 2-28.

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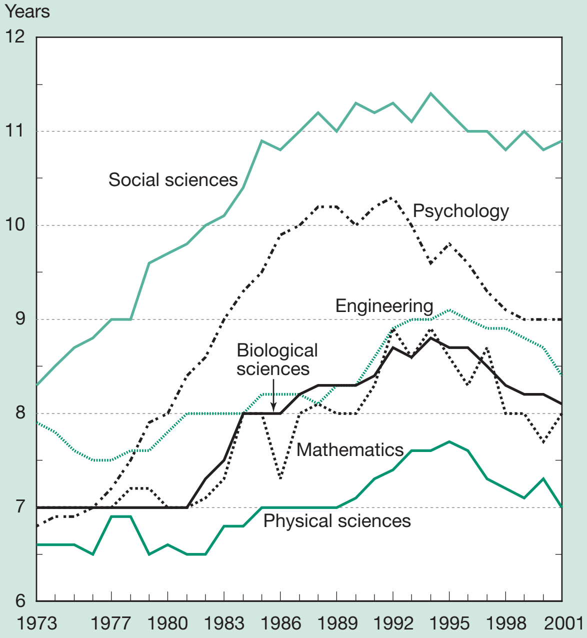
Figure 2-24
Time from bachelor's to S&E doctoral degree, by doctoral degree field: 1973–2001



NOTE: Values are median years between award of bachelor's degree and award of doctoral degree.

SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-29.

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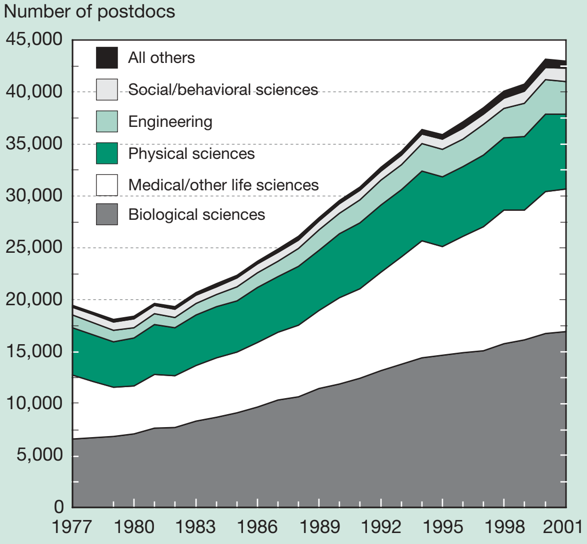
receiving a doctorate, but not all positions characterized as postdocs fit this description. Universities employ most postdocs, although not always under that title.

In 2001, there were almost 43,000 doctorate holders with science, engineering, or health postdoc appointments at U.S. universities, with approximately 30,000 of those in biological sciences and medical and other life sciences (figure 2-25) (NSF/SRS 2003a). More scientists have been taking such positions and, especially in life sciences, have been occupying them longer. According to data from NSF's Survey of Doctorate Recipients, before 1965, only 25 percent of all S&E doctorate holders ever had a postdoc appointment, and the average appointment lasted 20 months. In the cohort of students who graduated in 1989–91, however, 38 percent took postdoc appointments, with the average appointment lasting 29 months. These increases were most pronounced in biosciences (from 40 percent at 24 months in 1965 to 72 percent at 46 months in 1989–91) and physics (from 29 percent at 23 months in 1965 to 68 percent at 34 months in 1989–91) (chapter 3 and CPST 2003).

Data from the Survey of Graduate Students and Postdoctorates in Science and Engineering show that noncitizens account for much of the increase in the number of S&E postdocs (NSF/SRS 2003a). The number of foreign S&E postdocs (temporary residents) at U.S. universities increased from approximately 15,700 in 1991 to 24,600 in 2001. The number of U.S.-citizen and permanent-resident S&E postdocs at these institutions increased more modestly, from approximately 15,100 in 1991 to 18,400 in 2001 (figure 2-26 and appendix table 2-30).

Figure 2-25
Postdocs at U.S. universities, by field of doctoral degree: 1977–2001



NOTE: Data for 1978 are interpolated.

SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-30.

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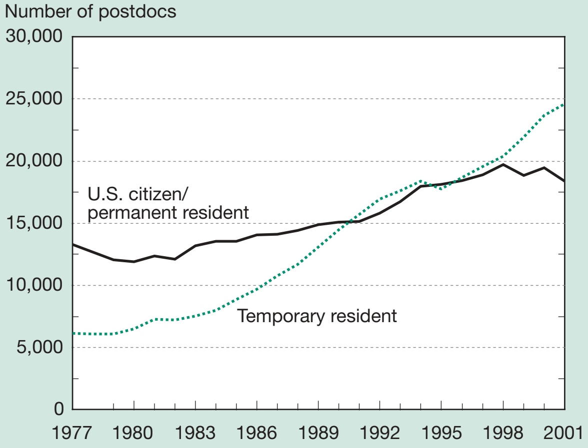
Figure 2-26
Postdocs at U.S. universities, by citizenship status: 1977–2001



NOTE: Data for 1978 are interpolated.

SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-30.

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The S&E community has become increasingly concerned about the well-being of postdocs and the effects that more and longer postdoc positions have on the attractiveness of S&E careers. Postdoc positions are often viewed as undesirable. Postdocs are paid less than other doctoral degree recipients; in 2001, the median salary for postdocs 1–3 years after completing their doctorate across all S&E fields was $33,000, whereas the median salary of nonpostdocs was $62,000 (CPST 2003). In addition, these positions often lack health insurance, retirement benefits, access to grievance procedures, pay raises, and annual reviews. The sidebar "Recent Developments Affecting Postdocs" describes some efforts to address the status of postdocs.

Foreign Doctoral Degree Recipients

Foreign recipients of U.S. doctoral degrees are an important part of the internationally mobile high-skilled labor force. When they return to their home countries or otherwise leave the United States after completing their degrees, they add to the stock of potential leaders in research and education, making those countries more competitive in S&E. Those who remain in the United States enhance the capability of U.S. S&E enterprise. In many cases, regardless of where they settle, their career trajectories foster ties between their countries of origin and the United States.

This section includes data on the places of origin of foreign doctorate recipients and on their stay rates in the United States after completing their degrees. The data are derived from the NSF Survey of Earned Doctorates, with special tabulations from 1985 to 2000.

Recent Developments Affecting Postdocs

The Committee on Science, Engineering, and Public Policy (COSEPUP) of the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies produced a guide for postdocs, universities, funding organizations, and disciplinary societies, *Enhancing the Postdoctoral Experience for Scientists and Engineers* (COSEPUP 2000). Suggestions included developing institutional policies concerning compensation, status, recognition, evaluation, health insurance, and standards for postdocs. The report also suggested setting time limits for postdoc appointments, providing career guidance, and improving the transition from postdoc position to permanent employment.

The National Postdoctoral Association (NPA) was established in 2003 to improve the working conditions of postdocs. It has received funding from the Alfred P. Sloan Foundation and assistance from the American Association for the Advancement of Science (AAAS). Its threefold mission is to provide a voice for postdocs; build consensus concerning best practices; and collaborate with government bodies, funding agencies, and professional organizations.

Science's Next Wave, a weekly online publication from *Science* magazine and AAAS dealing with scientific training, career development, and the job market, has launched Postdoc Network, a forum of practical information for postdocs and their mentors. To collect consistent data to aid policymaking on postdocs, Sigma Xi, the scientific research society, is collaborating with NPA on a postdoc survey project, to be administered in spring 2004.

Both Stanford University and the University of California have begun tackling the concerns of postdocs on their campuses. Stanford University has adopted, and University of California schools are considering adopting, policies that share certain elements (Christopherson 2002 and University of California System 2002). These include a minimum annual salary ($36,000 at Stanford and $29,000 at University of California schools); medical benefits; a 5-year limit for postdoc positions, after which postdocs may be hired in staff positions; a grievance policy; and a leave policy. Stanford is publishing a best-practices manual for postdocs and their mentors and is expanding its career center to help postdocs in their transition to permanent employment (Sreenivasan 2003).

Major Countries/Economies of Origin

Students from 11 major foreign countries/economies and three regional groupings together accounted for nearly 70 percent of all foreign recipients of U.S. S&E doctorates from 1985 to 2000. The major Asian countries/economies sending doctoral students to the United States have been China, Taiwan, India, and South Korea, in that order. Major European countries of origin have been Germany, Greece, the United Kingdom, Italy, and France. Data on regional groupings of other Western European, Scandinavian, and Eastern European countries are also given, as are data for Mexico and Canada. Because students from Asia represent such a large proportion of foreign S&E doctoral degree recipients at U.S. universities, trends in their earned degrees are examined separately.

Asia

U.S. S&E doctorates earned by Asian students increased from the mid-1980s to the mid- to late 1990s, followed by a decline. Most of the degrees were in engineering and biological and physical sciences. From 1985 to 2000, students from the four Asian countries/economies (China, Taiwan, India, and South Korea) earned more than 50 percent of S&E doctoral degrees awarded to foreign students in the United States (68,500 of 138,000), four times more than students from Europe (16,000).

From 1985 to 2000, students from the People's Republic of China earned, cumulatively, more than 26,500 S&E doctoral degrees at U.S. universities, mainly in biological and physical sciences and engineering (table 2-9). The number of S&E doctorates earned by Chinese students increased from 138 in 1985 to almost 3,000 in 1996. After this peak year, their number of doctorates from U.S. institutions declined and leveled off until 1999 and then increased slightly in 2000 and 2001.[12]

Students from Taiwan received the second-largest number of S&E doctorates at U.S. universities. Between 1985 and 2000, Taiwanese students earned almost 15,500 S&E doctoral degrees, mainly in engineering and biological and physical sciences (table 2-9). Taiwan was an early user of U.S. doctoral education. In 1985, students from Taiwan earned more U.S. S&E doctoral degrees than students from India and China combined. The Taiwanese number of degrees increased rapidly for almost a decade, from 746 in 1985 to 1,300 at their peak in 1994. However, as Taiwanese universities increased their capacity for advanced S&E education in the 1990s, S&E doctorates earned from U.S. universities by Taiwanese students declined from 1,300 in 1994 to 669 in 2000.[13]

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[12] The number of S&E doctoral degrees earned by Chinese students within Chinese universities continued to increase throughout the decade, from 1,069 in 1990 to 8,153 in 2001 (National Science Board 2002 and China's National Research Center for Science and Technology for Development, special tabulations, 2003).

[13] A current science and technology policy debate in Taiwan is focused on whether to encourage more Taiwanese to study at U.S. universities for the subsequent benefits of networking between Taiwanese and U.S. scientists and engineers.

Table 2-9
Asian recipients of U.S. S&E doctorates by field and country/economy of origin: 1985–2000

Field	All Asian recipients	China	Taiwan	India	South Korea
All fields	80,310	28,698	18,508	16,029	17,075
S&E	68,550	26,534	15,487	13,274	13,255
Physical sciences	11,987	6,356	1,923	1,856	1,852
Earth, atmospheric, and ocean sciences	1,731	972	327	180	252
Mathematics	3,585	1,954	614	438	579
Computer/information sciences	3,221	673	839	1,178	531
Engineering	25,923	7,207	7,518	6,146	5,052
Biological sciences	12,251	6,790	2,175	1,766	1,520
Agricultural sciences	2,333	901	601	316	515
Psychology/social sciences	7,519	1,681	1,490	1,394	2,954
Non-S&E[a]	11,760	2,164	3,021	2,755	3,820

[a] Includes medical and other life sciences.

NOTE: Foreign doctorate recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations, 2003.

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Table 2-10
European and North American recipients of U.S. S&E doctorates, by field and region/country of origin: 1985–2000

	Europe[a]				North America		
Field	Total	Western	Scandinavia	Eastern	Total	Mexico	Canada
All fields	21,525	15,840	1,386	4,299	9,423	2,501	6,922
S&E	16,123	11,277	1,023	3,823	6,075	2,077	3,998
Physical sciences	3,281	2,040	163	1,078	725	187	538
Earth, atmospheric, and ocean sciences	641	459	62	120	241	93	148
Mathematics	1,720	924	81	715	337	123	214
Computer/information sciences	756	520	57	179	172	52	120
Engineering	3,484	2,461	198	825	1,077	458	619
Biological sciences	2,347	1,690	136	521	1,244	381	863
Agricultural sciences	534	420	48	66	575	388	187
Psychology/social sciences	3,360	2,763	278	319	1,704	395	1,309
Non-S&E[b]	5,402	4,563	363	476	3,348	424	2,924

[a] See figure 2-28 for countries included in Western Europe, Scandinavia, and Eastern Europe.
[b] Includes medical and other life sciences.

NOTE: Foreign doctorate recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations, 2003.

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Indian students earned more than 13,000 S&E doctoral degrees at U.S. universities over the period, mainly in engineering and physical and biological sciences. They also earned by far the largest number of U.S. doctoral degrees awarded to any foreign group in computer and information sciences (table 2-9). The decade-long increase in U.S. S&E doctorates earned by Indian students ended in 1996, followed by 4 years of decline. The decline was particularly marked in engineering (57 percent) and computer sciences (50 percent).[14]

South Korean students earned more than 13,000 U.S. S&E doctorates, mainly in engineering, physical sciences, and psychology and social sciences (table 2-9). Their number of S&E doctoral degrees increased from 300 in 1985 to more than 1,000 in 1990, fluctuated around 1,000 for the first half of the 1990s, and then declined and leveled off at about 700 by the end of the decade.

Europe

European students earned less than one-fourth the number of S&E doctorates earned by Asian students and tended to focus more on social sciences and psychology than their Asian counterparts (table 2-10).

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[14] Increasing employment opportunities in IT and software engineering (in the United States and India) may have lessened the incentive for completing a doctoral degree in these fields.

Western European countries whose students earned the most U.S. S&E doctorates from 1985 to 2000 were Germany, Greece, the United Kingdom, Italy, and France, in that order. From 1985 to 1993, Greece and the United Kingdom were the primary European countries of origin; thereafter, their numbers of doctoral degree recipients declined and leveled off. Germany was the only major Western European country whose students earned an increasing number of U.S. S&E doctorates throughout the 1990s (figure 2-27).[15] Scandinavians received fewer U.S. doctorates than students from the other European regions, with a field distribution roughly similar to that for other Western Europeans.

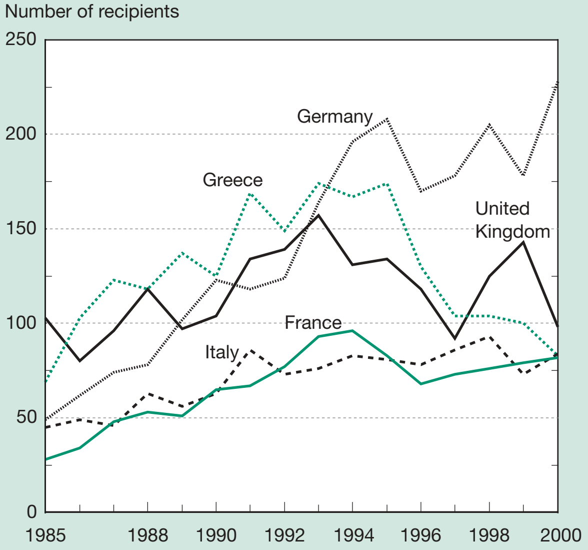
The number of Eastern European students earning S&E doctorates at U.S. universities increased from fewer than 100 in 1990 to more than 600 in 2000 (figure 2-28). A higher proportion of Eastern European (89 percent) than Western European (71 percent) recipients of U.S. doctorates were in S&E fields. Within S&E, Western Europeans were more likely to study psychology and social sciences and engineering, and Eastern Europeans tended to study physical sciences, engineering, and mathematics (table 2-10).

North America

The Canadian and Mexican shares of U.S. S&E doctoral degrees were small compared with those from Asia and Europe The number of degrees earned by Canadian students increased rapidly in the second half of the 1980s, from about 150 in 1985 to more than 300 in 1991, and then remained relatively stable in the 1990s. Fifty-eight percent of Canadian doctoral degree students in U.S. universities earned S&E doctorates, mainly in psychology and social and biological sciences (figure 2-29 and table 2-10). Mexican doctoral students in U.S. universities are more concentrated in S&E fields than are Canadian students. Eighty-three percent of the doctoral degrees earned by Mexican students at U.S. universities were in S&E fields, mainly engineering, psychology and social sciences, and biological and agricultural sciences. The number of doctoral degree recipients from Mexico fluctuated and increased slowly throughout the period, from 100 degrees earned in 1985 to more than 200 in 2000.

Figure 2-27

U.S. S&E doctoral degree recipients from selected Western European countries: 1985–2000



NOTE: Degree recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations, 2003.

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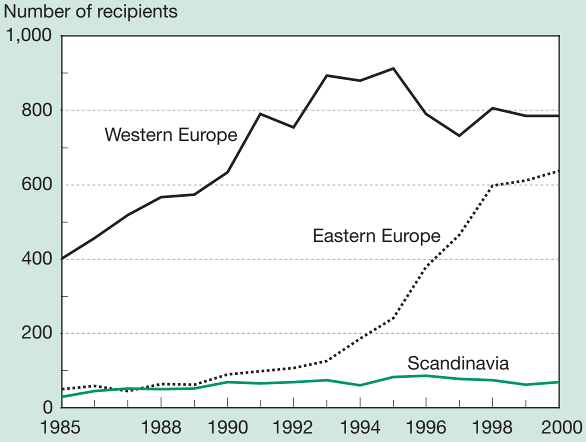
Figure 2-28

U.S. S&E doctoral degree recipients from Europe, by region: 1985–2000



NOTES: Degree recipients include permanent and temporary residents. Western Europe includes Andorra, Austria, Belgium, France, Germany, Gibraltar, Greece, Ireland, Italy, Luxembourg, Malta, Monaco, Netherlands, Portugal, Spain, and Switzerland. Eastern Europe includes Albania, Bulgaria, Czech Republic, Slovakia, Hungary, Poland, Romania, Russia, Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgystan, Latvia, Moldova, Tadjikistan, Turkmenistan, Ukraine, Uzbekistan, Yugoslavia, Bosnia-Herzogovina, Croatia, Macedonia, and Serbia-Montenegro. Scandinavia includes Denmark, Finland, Iceland, Norway, and Sweden.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations, 2003.

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Stay Rates

Almost 30 percent of the actively employed S&E doctorate holders in the United States are foreign born, as are many postdocs. Most of those working in the United States (excluding postdocs) obtained their doctorates from U.S. universities. Stay rates, based on stated plans at receipt of doctorate, indicate how much the United States relies on inflow of doctorate holders from different countries and whether working in the United States remains an attractive option for foreign students who obtain U.S. doctorates. In chapter 3, we report an analysis using a stay-rate measure

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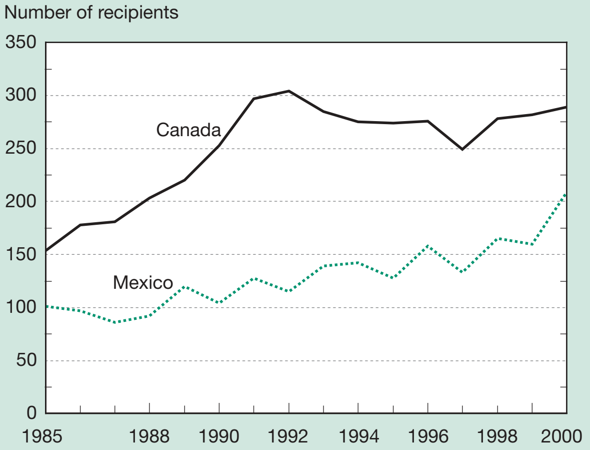
[15] Germany is also the top country of origin of foreign doctoral degree recipients at U.K. universities (National Science Board 2002). German doctoral programs are long, and students may prefer the shorter U.K. and U.S. degree programs.

Figure 2-29
U.S. S&E doctoral degree recipients from Canada and Mexico: 1985–2000



NOTE: Doctoral degree recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations, 2003.

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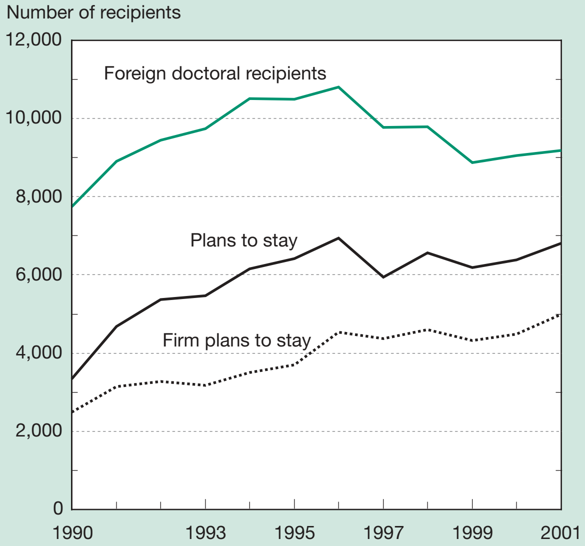
Figure 2-30
Plans of foreign recipients of U.S. S&E doctorates to stay in United States: 1990–2001



NOTES: Foreign doctoral recipients include permanent and temporary residents. Appendix table 2-31 includes plans to stay by place of origin and field of study in 3-year increments.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations, 2003. See appendix table 2-31.

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based on examination of Social Security records several years after the doctorate.

Historically, approximately 50 percent of foreign students who earned S&E degrees at universities in the United States reported that they planned to stay in the United States, and a smaller proportion said they had firm offers to do so (NSF/SRS 1998). However, these percentages increased significantly in the 1990s. In the 1990–93 period, for example, of the foreign S&E doctoral degree recipients who reported their plans, 63 percent planned to remain in the United States after receiving their degree, and 41 percent had firm offers. By the 1998–2001 period, 76 percent of foreign doctoral degree recipients in S&E fields with known plans intended to stay in the United States, and 54 percent accepted firm offers to do so (appendix table 2-31). Although the number of S&E doctoral degrees earned by foreign students declined after 1996, the number of students who had firm plans to remain in the United States declined only slightly from its 1996 peak. Each year from 1996 to 2000, around 4,500 foreign doctoral degree recipients had firm offers to remain in the United States at the time of degree conferral, with a slight increase in 2001 (figure 2-30).

Stay rates vary by place of origin. From 1985 to 2000, most U.S. S&E doctoral degree recipients from China and India planned to remain in the United States for further study and employment. In 2001, 70 and 77 percent, respectively, reported accepting firm offers for employment or postdoctoral research in the United States (figure 2-31).

Recipients from South Korea and Taiwan are less likely to stay in the United States. Over the 1985–2000 period, only 26 percent of South Koreans and 31 percent of Taiwanese reported accepting firm offers to remain in the United States. Both the number of S&E students from these Asian economies and the number who intended to stay in the United States after receipt of their doctoral degree fell in the 1990s. This decline may be because Taiwan and South Korea have expanded and improved their advanced S&E programs and created R&D institutions that offer more attractive S&T careers for their expatriate scientists and engineers. Still, by 2001, about 50 percent of their new U.S. doctorate holders reported accepting U.S. appointments.

Historically, a relatively high percentage of U.S. S&E doctoral degree recipients from the United Kingdom planned to stay in the United States, whereas France and Italy had small percentages compared with other Western European countries (NSF/SRS 1998). However, by 2001, 50 percent or more of the doctoral degree students from these countries had firm plans to stay, as did those from Germany (figure 2-31). Stay rates for Eastern European doctoral degree recipients were high, exceeded only by those for India (appendix table 2-31).

The percentage of doctoral degree students who had firm plans to stay in the United States in 2001 was higher for Canada (58 percent) than for Mexico (38 percent), which has one of the lowest stay rates of all the major countries of origin of foreign U.S. doctoral degree recipients (figure 2-31).[16]

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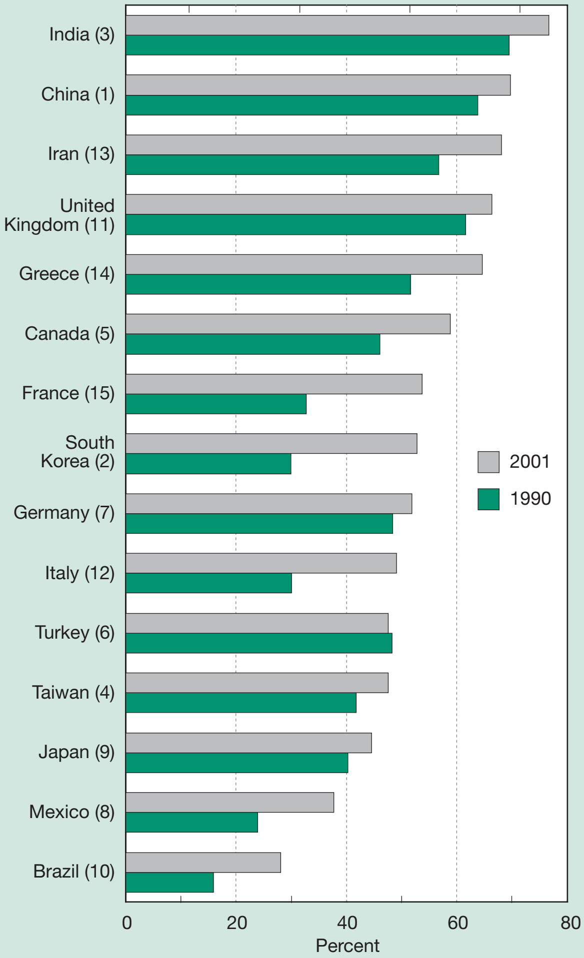
[16] The Mexican government's scholarship-loan programs erase the debt for those who enter public research universities on their return from overseas study (National Council for Science and Technology 2001).

A study of U.S. doctoral degree recipients from foreign countries explored the factors affecting the decision to stay in the United States (Gupta, Nerad, and Cerny 2003). The study cited numerous factors, stressing the strength of preexisting ties to the recipients' home countries. Among the doctorate holders studied, the principal source of funding was related to their likelihood of staying in the United States: those who stayed were more likely to have been funded primarily by RAs and TAs, and those who returned to their home countries were more likely to have relied on funding from their national government or their employer.

Figure 2-31
Short-term stay rates of foreign recipients of U.S. S&E doctorates, by place of origin: 1990 and 2001



NOTES: Numbers in parentheses rank the top 15 places of origin of foreign recipients of U.S. S&E doctorates conferred in 2001. Short-term stay rates count those with firm commitments of postaward employment or postdoctoral employment. Longer-term stay rates may differ. Appendix table 2-31 includes plans to stay by place of origin and field of study in 3-year increments.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations, 2003.

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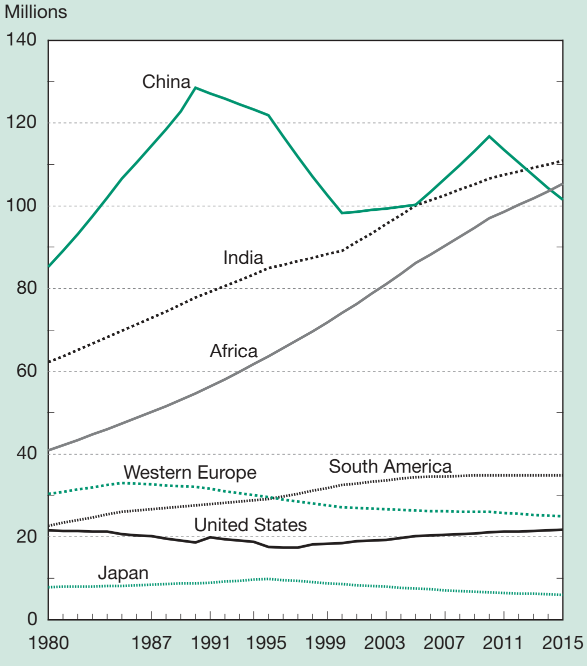
International S&E Higher Education

Excellence in S&E higher education helps a country to be technologically innovative and economically competitive (Greenspan 2000). Recognizing this, other countries are seeking to improve their relative standing in this area. This section places data on U.S. S&E higher education in an international comparative perspective. It presents available data on bachelor's (first university) degrees, including selected disaggregations by field and sex. It also compares participation rates in S&E degrees in different countries, including data on foreign student enrollment and degrees for selected countries.

The college-age cohort decreased in all major industrialized countries either in the 1980s or 1990s, although for different durations and to varying degrees (appendix table 2-32). To produce enough S&E graduates for increasingly knowledge-intensive societies, industrialized countries have sought to enroll a higher proportion of their citizens in higher education, train a higher proportion in S&E, and recruit S&E students from other countries, especially in the developing world. For example, China and India each has more than 90 million people of college age and is a major country of origin for foreign graduate students in the United States. Figure 2-32 shows that by 2015, the college-age cohort in Africa will surpass that of China.

Figure 2-32
Trends in population of 20–24-year-olds, by selected countries/regions: 1980–2015



SOURCES: United Nations Population Division, *World Population Prospects: The 2002 Revision*; and U.S. Bureau of the Census, Population Division, *Projections of the Resident Population by Age, Sex, Race, and Hispanic Origin: 1999 to 2100*. See appendix table 2-32.

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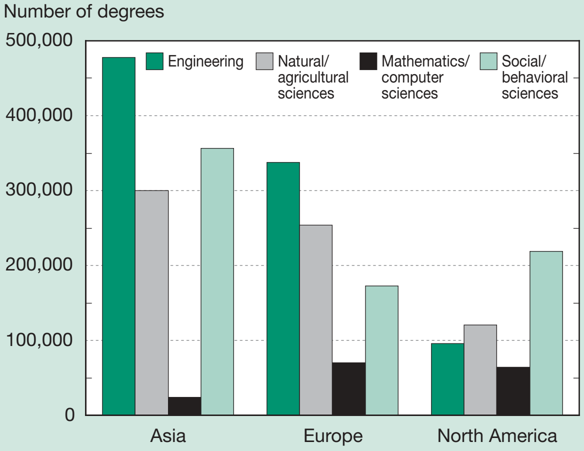
International Degree Trends

The availability and quality of international degree data vary. Major efforts of international statistical agencies have been under way for more than a decade to improve collection, reporting, and dissemination of these data.[17]

First University Degrees in S&E Fields

In 2000, more than 7.4 million students worldwide earned a first university degree,[18] and about 2.8 million of the degrees were in S&E fields: more than 1 million in engineering, almost 850,000 in social and behavioral sciences, and almost 1 million in mathematics and natural, agricultural, and computer sciences combined (appendix table 2-33). These worldwide totals only include countries for which data are readily available (primarily the Asian, European, and American regions) and are therefore an underestimation. Asian universities accounted for almost 1.2 million of the world's S&E degrees in 2000, with almost 480,000 degrees in engineering (figure 2-33). Students across Europe (including Eastern Europe and Russia) earned more than 830,000 S&E degrees, and students in North America earned more than 500,000.

Figure 2-33
First university S&E degrees in Asia, Europe, and North America, by field: 2000



NOTE: Natural sciences include physical, biological, earth, atmospheric, and ocean sciences.

SOURCES: Organization for Economic Co-operation and Development, *Education at a Glance 2002*; United Nations Educational, Scientific, and Cultural Organization (UNESCO), UNESCO Institute for Statistics database; and national sources. See appendix table 2-33 for countries/economies included in each region.

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Although the United States has historically been a world leader in offering broad access to higher education, many other countries now provide comparable access. The ratio of bachelor's degrees earned in the United States to the population of the college-age cohort remained relatively high at 33.8 per 100 in 2000 (appendix table 2-33). However, nine other countries also provided a college education to at least one-third of their college-age population.

A workforce trained in NS&E is indispensable to a modern economy. The proportion of the college-age population that earned degrees in NS&E fields was substantially larger in more than 16 countries in Asia and Europe than in the United States in 2000. The United States achieved a ratio of 5.7 per 100 after several decades of hovering between 4 and 5. Other countries/economies have recorded bigger increases: South Korea and Taiwan increased their ratios from just over 2 per 100 in 1975 to 11 per 100 in 2000–01. At the same time, several European countries have doubled and tripled their ratios, reaching figures between 8 and 11 per 100 (figure 2-34).

In several emerging Asian countries/economies, the proportion of first university degrees earned in S&E was higher than in the United States. For the past 3 decades, S&E degrees have made up about one-third of U.S. bachelor's degrees. The corresponding figures were considerably higher for China (59 percent in 2001), South Korea (46 percent in 2000), and Japan (66 percent in 2001) (appendix table 2-33).

In engineering fields, the contrast between the United States and other relatively advanced regions becomes sharper. Compared with Asia and Europe, the United States has a relatively low proportion of S&E bachelor's degrees in engineering. In 2000, students in Asia and Europe earned 40–41 percent of their first university S&E degrees in engineering. In contrast, students in the United States earned about 15 percent of their S&E bachelor's degrees in engineering fields (appendix table 2-33).

Long-term trend data on first university S&E degrees, available for selected countries, show strong growth in the 1990s in China and Japan (with a leveling off in 2000–01) and steady growth in South Korea, the United Kingdom, and the United States (figure 2-35). In the late 1990s, first university S&E degrees (of long duration) declined in Germany.[19] Germany had a sharp decline in engineering degrees, from 16,000 in 1998 to 9,000 in 2001 (Grote 2000 and appendix table 2-34).

International Comparison of Participation Rates by Sex

Among large Western countries for which first university degree data are available by sex, France, the United Kingdom, Spain, Canada, and the United States had relatively

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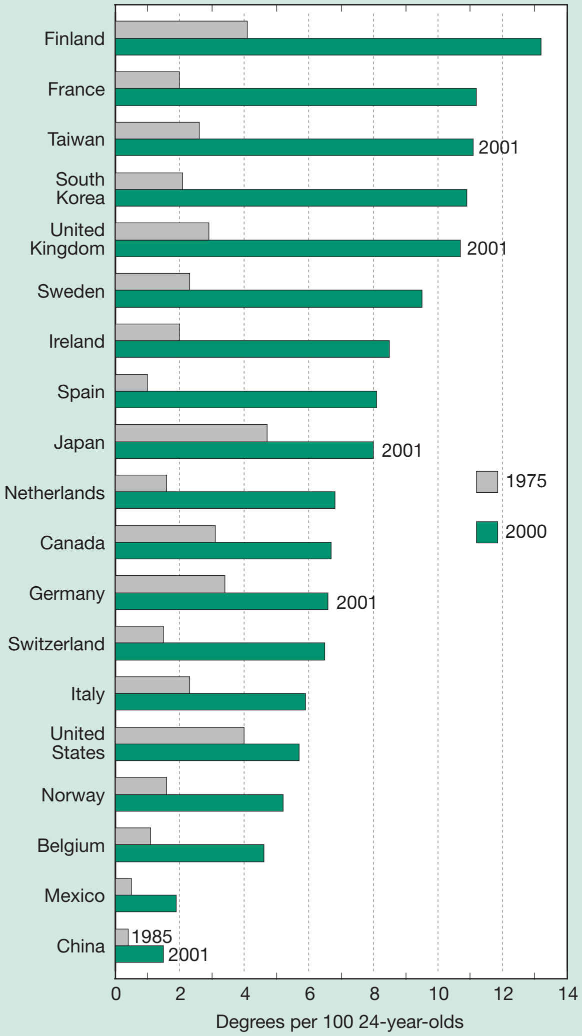
[17] Organisation for Economic Co-operation and Development, *Education at a Glance,* 2000, includes data on member countries; UNESCO Institute for Statistics (UIS) is giving within-country statistical training to expand the number of developing countries providing recent reliable data and validating the reported data within UIS.

[18] A first university degree refers to completion of a terminal undergraduate degree program. These degrees are classified as level 5A in the International Standard Classification of Education (ISCED 97), although individual countries use different names for the first terminal degree; for example, *laureata* in Italy, *diplome* in Germany, *maîtrise* in France, and *bachelor's degree* in the United States and Asian countries.

[19] The German data in figure 2-35 include only the long first university degree, which is required for further study. In 2001, an additional 40,000 S&E degrees were earned within *Fachhochschulen*, which are 3–5-year programs (appendix table 2-34).

Figure 2-34

Ratio of first university NS&E degrees to 24-year-old population, by country/economy: 1975 and 2000 or most recent year



NS&E natural sciences and engineering

NOTES: NS&E includes natural (physical, biological, earth, atmospheric, and ocean sciences), agricultural, and computer sciences; mathematics; and engineering. The ratio is the number of earned degrees in these fields per 100 24-year-olds.

SOURCES: Organization for Economic Co-operation and Development, *Education at a Glance 2002;* and national sources. See appendix table 2-33 for most recent data.

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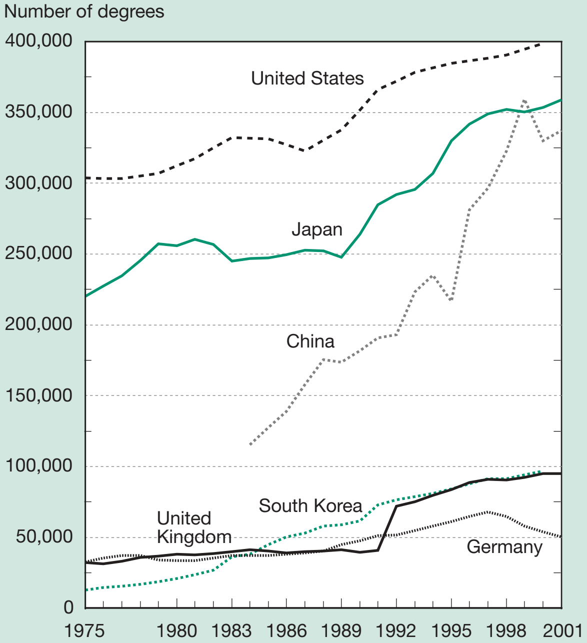
high participation rates for both men and women. In 2000, the ratio of female-earned first university degrees to the female 24-year-old population was about the same in France and the United Kingdom (41 per 100), Spain and the United States (39 per 100), and Canada (38 per 100). Women in the United Kingdom and France also had high participation rates in earned NS&E bachelor's degrees. In 2000, the ratio of NS&E degrees earned by women to the female 24-year-old population in the United Kingdom and France was 8 per 100. In France, this rate was more than half the rate for men.

Figure 2-35

S&E first university degrees, by selected countries: 1975–2001



NOTE: German degrees include only long university degrees required for further study.

SOURCES: China—National Research Center for Science and Technology for Development, special tabulations; Japan—Government of Japan, Monbusho Survey of Education; South Korea—Ministry of Education, *Statistical Yearbook of Education,* and Organisation for Economic Co-operation and Development, *Education at a Glance 2002;* United Kingdom—Higher Education Statistics Agency, special tabulations; Germany—Federal Statistical Office, *Prüfungen an Hochschulen;* and United States—National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-34.

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In the United States, participation rates in NS&E degrees were 4.5 per 100 for women and 6.8 per 100 for men (appendix table 2-35).

In Japan, Taiwan, and South Korea, women earn first university degrees at a rate similar to that in many European countries. However, women have high participation rates in NS&E only in South Korea and Taiwan. In 2000–01, the ratio of female-earned degrees in these fields to the female 24-year-old population was 7.4 per 100 in South Korea and 5.0 per 100 in Taiwan, higher than the participation rate of women in Japan, Germany, or the United States. Among reporting countries, women earned the highest proportion of their S&E degrees in natural and social sciences (appendix table 2-35).

International Comparison of Doctoral Degrees in S&E Fields

The proportion of S&E doctoral degrees earned outside the United States appears to be increasing. Of the 114,000 S&E doctoral degrees earned worldwide in 2000, 89,000 were earned outside the United States (appendix table 2-36). Figure 2-36 shows the breakdown of S&E doctoral degrees by major region and selected fields.

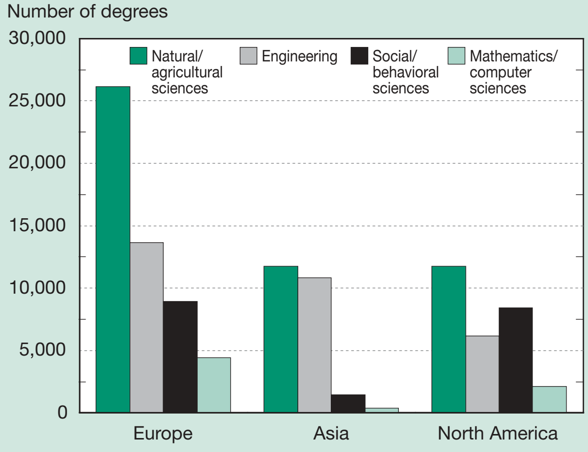
The proportion of S&E doctoral degrees earned by women is increasing in several world regions. In 2000, women earned more than 35 percent of S&E doctorates in several countries of Western Europe (Finland, France, Spain, Ireland, and Italy) and Eastern Europe (Bulgaria, Croatia, and Georgia). In the same year, women earned more than 40 percent of the doctoral degrees awarded in natural sciences in these countries (appendix table 2-37).

For most of the past 2 decades, momentum in NS&E doctoral degree programs has been strong in the United States and some Asian and European countries. Japan's 1993 national science policy to increase basic research for innovation led to a doubling of university research funding by 1997 and significant expansion of university doctoral programs. There was even stronger growth in China, and, by 2001, China was the largest producer of NS&E doctoral degrees in the Asian region. However, in the late 1990s, NS&E doctoral degrees leveled off in Germany and declined in the United States (figure 2-37). Figure 2-38 shows trends in NS&E doctoral degrees by region.

International Student Mobility

The 1990s witnessed a worldwide increase in the number of students going abroad for higher education study to the well-established destinations of the United States, the United Kingdom, and France. However, other countries, including Japan, Canada, and Germany, also expanded their enrollment of foreign S&E graduate students.

Figure 2-36
S&E doctoral degrees in Europe, Asia, and North America, by field: 2000 or most recent year



NOTES: Natural sciences include physical, biological, earth, atmospheric, and ocean sciences. Asia includes China, India, Japan, South Korea, and Taiwan. Europe includes Western, Central, and Eastern Europe. See appendix table 2-36 for countries/economies included within each region.

SOURCES: Organization for Economic Co-operation and Development, *Education at a Glance 2002;* United Nations Educational, Scientific, and Cultural Organization (UNESCO), UNESCO Institute for Statistics database; and national sources. See appendix table 2-36.

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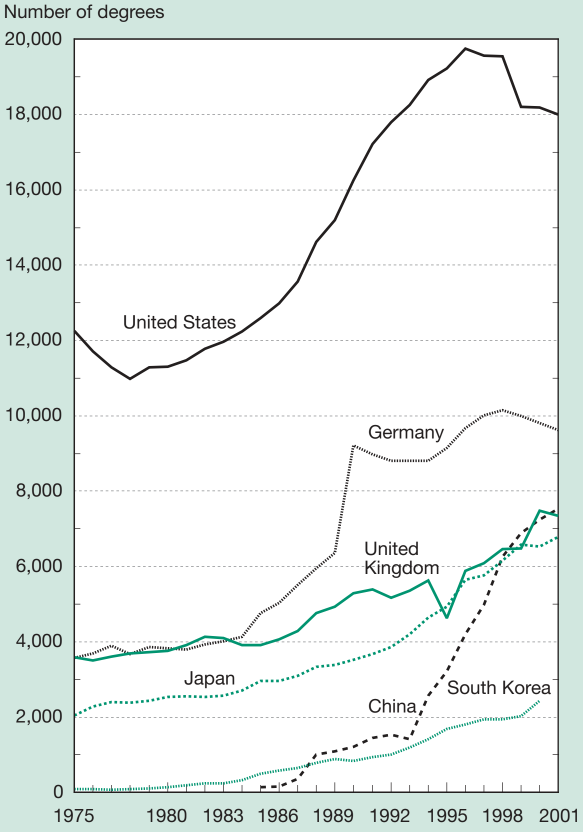
Foreign Enrollment in S&E in Selected Foreign Countries

The United States shares a tradition with France and the United Kingdom of educating large numbers of foreign students. In recent years, universities in other countries, notably Canada, Germany, and Japan, have also increased their number of foreign students.

Many of the United Kingdom's foreign students come from Britain's former colonies in Asia and North America (particularly India, Ireland, Malaysia, Singapore, Hong

Figure 2-37
NS&E doctoral degrees, by selected countries: 1975–2001



NS&E natural sciences and engineering

NOTE: NS&E includes natural (physical, biological, earth, atmospheric, and ocean sciences), agricultural, and computer sciences; mathematics; and engineering.

SOURCES: China—National Research Center for Science and Technology for Development, special tabulations; United States—National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates; Japan—Government of Japan, Monbusho Survey of Education; South Korea—Ministry of Education, *Statistical Yearbook of Education,* and Organisation for Economic Co-operation and Development, *Education at a Glance 2002;* United Kingdom—Higher Education Statistics Agency; and Germany—Federal Statistical Office, *Prüfungen an Hochschulen*. See appendix tables 2-38 and 2-39.

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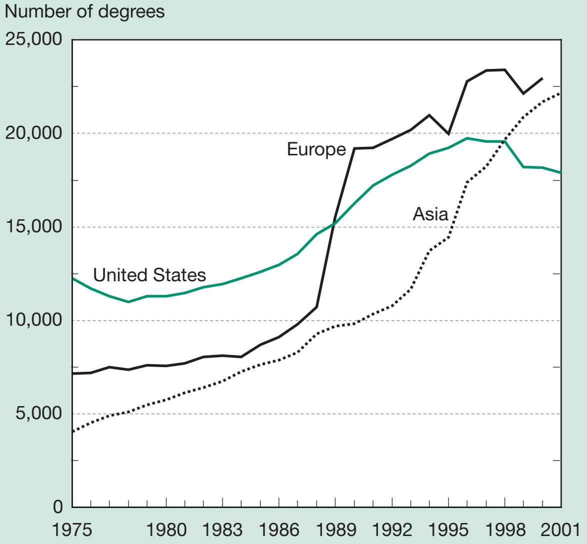
Figure 2-38
NS&E doctoral degrees in United States, Europe, and Asia: 1975–2001



NS&E natural sciences and engineering

NOTES: NS&E includes natural (physical, biological, earth, atmospheric, and ocean sciences), agricultural, and computer sciences; mathematics; and engineering. Europe includes only France, Germany, and the United Kingdom. Asia includes only China, India, Japan, South Korea, and Taiwan. The jump in the European data in 1989 is due to the inclusion of French data, which were unavailable in this data series before 1989. French data are estimated for 2000.

SOURCES: France—National Ministry of Education and Research, *Rapport sur les Études Doctorales;* Germany— Federal Statistical Office, *Prüfungen an Hochschulen;* United Kingdom—Higher Education Statistics Agency, special tabulations; China—National Research Center for Science and Technology for Development; India—Department of Science and Technology, *Research and Development Statistics;* Japan—Government of Japan, Monbusho Survey of Education; South Korea—Ministry of Education, *Statistical Yearbook of Education;* and Organisation for Economic Co-operation and Development, *Education at a Glance 2002;* Taiwan—Ministry of Education, *Educational Statistics of the Republic of China;* and United States—National Science Foundation, Division of Science Resources Statistics, *Science and Engineering Doctorate Awards*. See appendix tables 2-26, 2-38, and 2-39.

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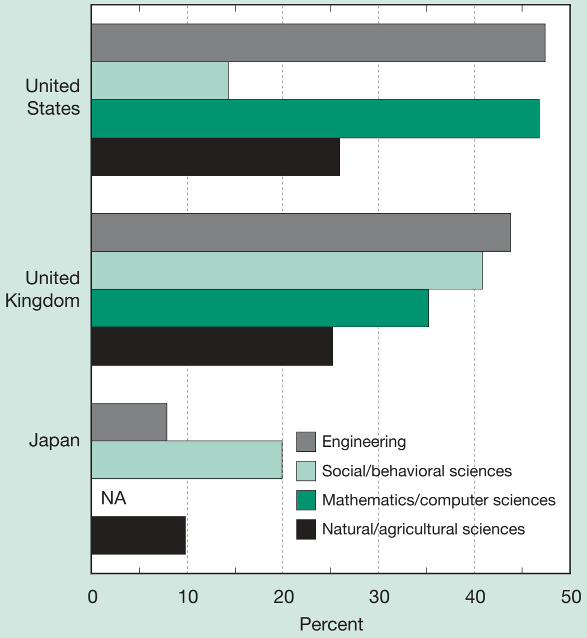
Kong, the United States, and Canada). In the 1990s, it began receiving more students from countries inside the European Union (EU). For example, in 1994, within the 10 top countries of origin, the number of foreign students from EU countries and former colonies were roughly equal. By 1998, in both graduate and undergraduate S&E programs, EU students were far more numerous in U.K. universities than students from former colonies. The number of students from China and Taiwan was also increasing (appendix table 2-40).

With an inflow of students from a broadening number of countries in the 1990s, the proportion of foreign students studying S&E in the United Kingdom increased at both the graduate and undergraduate level. Foreign undergraduate students in S&E increased from about 9 percent to almost 12 percent from 1995 to 1999, leveled off, and then declined in 2001. In undergraduate engineering, foreign student enrollment rose from 16,000 in 1995 to 21,000 in 1999 (the peak year for foreign undergraduate students), even as overall engineering enrollment declined from 113,000 to 100,000 (appendix table 2-40). At the graduate level, foreign S&E student enrollment increased continuously, from almost 29,000 in 1995 to 44,000 in 2001. By 2001, foreign students in the United Kingdom represented 44 percent of enrollment in graduate engineering programs and 35 percent in mathematics and computer sciences (figure 2-39).

Like the United Kingdom, France has a long tradition of educating students from its former colonies, as well as from developing countries in Africa and Latin America. In 1999, 7 of the 10 top countries of origin of foreign doctoral degree students in France were African (primarily Algeria, Morocco, and Tunisia) and Latin American (Brazil and Mexico) (National Science Board 2002). Also like the United Kingdom, the proportion of foreign students studying S&E fields in France increased at both the graduate and undergraduate level. Foreign undergraduate S&E enrollment in France increased from 7 percent in 1996 to 13 percent in 2002. In

Figure 2-39
Foreign S&E graduate student enrollment in selected countries, by field: 2001



NA not available

NOTES: Japanese data include mathematics in natural sciences and computer sciences in engineering. Natural sciences include physical, biological, earth, atmospheric, and ocean sciences. Foreign graduate enrollment in U.S. data includes temporary residents only; U.K. and Japanese data include permanent and temporary residents.

SOURCES: United States—National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov; United Kingdom—Higher Education Statistics Agency, special tabulations; and Japan—Government of Japan, Ministry of Education, Culture and Science, Division of Higher Education, special tabulations, 2003. See appendix tables 2-12, 2-40, and 2-42.

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the same period, foreign graduate S&E enrollment increased from 20 to 25 percent. Foreign graduate enrollment was higher in engineering fields, reaching 33 percent in 2002 (appendix table 2-41).

Japan, Canada, and Germany are also attempting to bolster enrollment of foreign students in S&E fields. Japan's goal of 100,000 foreign students, first promulgated in the early 1980s, is gradually being achieved. In 2001, almost 70,000 foreign students, mainly (more than 95 percent) from the Asian region enrolled in Japanese universities, and preliminary data for 2002 suggest that foreign enrollment has reached 100,000. In 2001, foreign student enrollment was concentrated at the undergraduate level (44,500) and in social and behavioral sciences (46 percent of undergraduates enrolled).[20] Japan also enrolled about 25,000 foreign students at the graduate level, mainly from China and South Korea, and foreign students represented 12 percent of the graduate students in S&E fields (appendix table 2-42).

Like the United Kingdom, Canada has traditionally educated foreign students from British Commonwealth countries. In 1985, these countries were 6 of the 10 top countries of origin of foreign S&E students in Canada. As foreign student flows increased in the 1990s, the top countries of origin of foreign students in Canada shifted toward non-Commonwealth countries in Asia, Europe, and the Middle East (appendix table 2-43).[21]

From 1985 to 1998, Canada enrolled an increasing number of foreign students in its graduate and undergraduate S&E programs. By 1998, 16,700 foreign graduate S&E students were enrolled in Canadian universities, up from 9,400 in 1985. In 1998, foreign students represented about 9 percent of undergraduate enrollment in S&E fields, with larger percentages in mathematics and physical sciences (16 percent) and engineering and applied sciences (13 percent). These percentages were up slightly from 1985 (appendix table 2-43). Foreign students represented 21 percent of all graduate S&E students in Canada in 1998, compared with 17 percent in 1985, with higher foreign representation in mathematics and physical sciences (30 percent) and engineering and applied sciences (32 percent).

Germany is recruiting students from India and China to fill its research universities, particularly in engineering and computer sciences (Grote 2000 and Koenig 2001). Germany has also established bachelor's and master's degree programs taught in English to attract students from the United States, Europe, and other countries. Since 2000, Germany's report of higher education statistics has included earned bachelor's and master's degrees in these new types of programs.

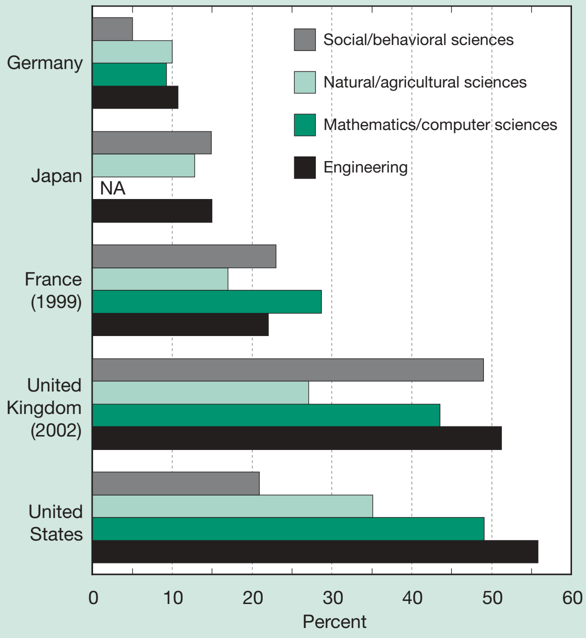
International Comparison of Foreign Doctoral Degree Recipients

Like the United States, the United Kingdom and France have many foreign students among their S&E doctoral degree recipients. By 2001, around 36 percent of S&E doctorates from U.K. and U.S. universities were awarded to foreign students. Almost 21 percent of French S&E doctoral recipients were foreign (appendix table 2-44).

The percentage of foreign doctoral degree recipients was generally higher in engineering, mathematics, and computer sciences. Foreign students earned 56 percent of the engineering degrees awarded by U.S. universities, 51 percent of those awarded by U.K. universities, and 22 percent of those awarded by French universities. Foreign students earned 49 percent of the mathematics and computer science doctorates awarded by U.S. universities, 44 percent of those awarded by U.K. universities, and 29 percent of those awarded by French universities. In addition, Japan and Germany had a modest but growing percentage of foreign students among their S&E doctoral degree recipients (figure 2-40 and appendix table 2-44).

The internationalization of S&E higher education can benefit both industrialized and developing countries. (See sidebar, "Contributions of Developed Countries to Increasing Global S&E Capacity.")

Figure 2-40
S&E doctoral degrees earned by foreign students in selected countries, by field: 2001 or most recent year



NA not available

NOTES: Japanese data are for university-based doctorates only; excludes *ronbun hakase* doctorates awarded for research within industry. Japanese data include mathematics in natural sciences and computer sciences in engineering. For each country, data are for doctoral degree recipients with foreign citizenship, including permanent and temporary residents. Natural sciences include physical, biological, earth, atmospheric, and ocean sciences.

SOURCES: France—National Ministry of Education and Research, *Rapport sur les Études Doctorales 2001;* Germany— Federal Statistical Office, *Prüfungen an Hochschulen 2001;* Japan—Government of Japan, Ministry of Education, Culture and Science, Division of Higher Education, special tabulations; United Kingdom—Higher Education Statistics Agency, special tabulations, 2003; and United States—National Science Foundation, Division of Science Resources Statistics, *Science and Engineering Doctorate Awards: 2001*. See appendix table 2-44.

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[20] At the undergraduate level, about 20 percent of foreign students are permanent residents in Japan. In contrast, at the graduate level, only 5 percent of foreign students are permanent residents.

[21] Unpublished tabulations provided by Statistics Canada, 2002.

Contributions of Developed Countries to Increasing Global S&E Capacity

The doctoral faculty in many developing and emerging countries have been trained in Western industrialized countries.[*] From 1985 to 2001, U.S. universities trained 148,000 foreign doctoral students in S&E fields (appendix table 2-28). Most (89 percent) of these foreign doctoral degree recipients were from developing countries/economies throughout the world, particularly Asia.[†] In addition, the United Kingdom, France, and Canada contributed significantly to educating many S&E students from developing countries, at both the graduate and undergraduate level. As student mobility increases, particularly for graduate S&E education, host countries receive students from a broader spectrum of developing countries (appendix tables 2-40, 2-42, and 2-43).

Foreign S&E doctoral degree recipients who returned home after study abroad have contributed to the expansion of S&E graduate programs and the improvement of faculty credentials and research capacity in several developing countries. U.S. S&E doctoral degree recipients from China who returned home in the 1980s expanded higher education and graduate S&E programs. China's successful participation in the Human Genome Project in the 1990s was facilitated by recruiting Chinese scientists and engineers educated abroad to 20 institutes in Beijing and Shanghai (Li 2000). The return flow of South Korean and Taiwanese S&E doctoral degree recipients from U.S. universities in the 1980s and 1990s was often to faculty positions within their home country (Song 1997).

Foreign doctoral degree recipients who remain abroad become part of an increasingly international S&E higher education system and often participate in international collaborative research. By the end of the 20th century, about 35 percent of the computer science and engineering faculties at U.S. universities and colleges were foreign born, as were nearly 30 percent of mathematics faculty and about 20 percent of the faculties in physical, life, and social sciences (National Science Board 2002). International collaborations that include U.S. S&E faculty contribute to research programs that strengthen the scientific capacity of developing countries.[‡] For example, Biocomplexity in the Environment encourages international biodiversity research on therapeutic plants in the context of conservation and sustainable economic development and includes funds for equipment and human resource development in developing countries. U.S. universities are attempting to create an Internet-based worldwide materials research network to enhance scientific and educational collaborations. Materials Research Science and Engineering Centers within U.S. universities have active international collaborations between U.S. researchers and educators and their counterparts in Africa, the Americas, Asia, Europe, and the Pacific region.[§]

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[*] College catalogs in developing countries generally list faculty with the name of the university and department in which they earned their doctorate.

[†] National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations, 2003.

[‡] U.S. institutions and S&E faculty are active in international distance education in developing countries, advise on establishing centers of excellence, accept students from abroad, and establish international collaborative research with their former students. For more information, see Arnone (2001) and Takle (1999).

[§] For more information, see *International Dimensions of NSF Research & Education,* http://www.nsf.gov/sbe/int/pubs/02overview/start.htm.

Conclusion

Governments around the world are expanding access to higher education to develop an educated workforce that will contribute to economic growth and competitiveness. Many countries have successfully increased the rate at which their college-age citizens earn S&E degrees. The United States has been less successful in this regard, particularly in the combined natural sciences, mathematics, computer sciences, and engineering fields that are considered critical to technological innovation. At the same time, mature industrial countries facing adverse demographic shifts are considering strategies to import highly trained foreign labor, especially from developing nations.

In the United States, freshmen continue to show considerable interest in S&E fields and appear to be no less prepared to undertake such study than they were 1 or 2 decades ago. However, sizable numbers indicate a need for remedial instruction in mathematics and the sciences, perhaps indicating weak spots in students' secondary education. In any case, as the number of U.S. bachelor's degrees has expanded, the share going to S&E degrees has held steady. However, shifts among S&E fields have been toward biological, social, and behavioral sciences and away from physical sciences and engineering.

Demographic trends that will shape U.S. higher education can already be seen. Women now represent the majority of students; they also earn most of the bachelor's degrees and half of the bachelor's degrees in S&E. Minority students from all groups are earning greater degree shares, with faster progress at the lower degree levels than at the doctorate level. As the share of underrepresented minorities in the college-age population grows, it is critical to entice them into S&E fields, where their attainment gap with whites remains large.

At advanced education levels, these trends come into sharper focus. Declining numbers of white men complete advanced S&E training; some of the women's numbers are also becoming flat or declining. Growing populations of minority groups counterbalance some of this trend, but growth in advanced S&E degrees primarily reflects strongly rising numbers of foreign students.

Through 2001, the last year of available data, the U.S. retained and even increased its attractiveness to these foreign students. The rate at which doctoral students remained here after receipt of their doctorate rose well above longer-term averages during the late 1990s. In the period 1998–2001, 76 percent reported plans to stay, and 54 percent had firm commitments to do so.

Nonetheless, the worldwide economic downturns and the events of September 11, 2001, introduce uncertainties into this picture. The latter especially has long-term ramifications, and even the initial impact is not yet captured in these data. Some evidence suggests that lower numbers of student and exchange visas are being granted. At this writing, it is unclear to what extent this evidence represents fewer applications, slower or more critical processing, a change in relative economic conditions, or a combination of these and other factors.

These developments occur in the context of continuing extension of global markets; worldwide reach of networks of scientific and technical activity, cooperation, and competition; and global flows of highly trained personnel. As government efforts to develop centers of excellence bear fruit, and as industry locates in developing markets and regions with newly developed technological competency, continuing shifts will take place in the international distribution of jobs and employment requiring high skill levels and technically sophisticated training. The shifts will, in turn, elicit responses from worldwide higher education systems.

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Highlights

- **Since 1980, the number of nonacademic science and engineering jobs has grown at more than four times the rate of the U.S. labor force as a whole.** Nonacademic S&E jobs increased by 159 percent between 1980 and 2000, an average annual growth rate of 4.9 percent (compared with 1.1 percent for the entire labor force).
- **Even among S&E bachelor's degree holders working in non-S&E occupations, more than two-thirds reported that their job related to their field of degree.** Because individuals use S&E knowledge in a wide variety of areas, a purely occupation-based definition of the S&E labor force is too limiting.
- **Barring changes in degree production or in immigration, the S&E labor force will grow at a slower rate and the average age of scientists and engineers will increase.** The age distribution of individuals with S&E degrees implies this change.
- **The total number of retirements among S&E-degreed workers will increase dramatically over the next 20 years, barring large changes in retirement rates.** More than half of S&E-degreed workers are age 40 or older, and the 40–44 age group is nearly four times as large as the 60–64 age group.
- **Labor market conditions for individuals with S&E degrees improved during the 1990s; however, unemployment in S&E occupations reached a 20-year high in 2002.** Holders of S&E bachelor's degrees had lower unemployment rates and were significantly more likely to work in jobs related to their degree in 1999 compared with 1993. However, by 2002, overall unemployment rates for individuals in S&E occupations (regardless of education) had risen to 3.9 percent.
- **The share of foreign-born scientists and engineers in the U.S. S&E workforce rose to a record in 2000, reflecting high levels of entry by both permanent and temporary visa holders during the 1990s.** Data from the 2000 U.S. Census show that, in S&E occupations, approximately 17 percent of bachelor's degree holders, 29 percent of master's degree holders, and 38 percent of doctorate holders are foreign born.
- **A decline in student, exchange, and temporary high-skilled worker visas issued since 2001 interrupted a long-term trend of growth.** The number of student visas and of temporary high-skilled worker visas issued both declined by more than one-fourth since FY 2001. These declines were due both to fewer applications and to an increase in the proportion of visa applications rejected.
- **There is increased recruitment of high-skilled labor, including scientists and engineers, by many national governments and private firms.** For example, in 1999, 241,000 individuals entered Japan with temporary high-skill work visas, a 75 percent increase over 1992.

Introduction

Chapter Overview

Although workers with science and engineering skills make up only a small fraction of the total U.S. civilian labor force, their impact on society belies their numbers. These workers contribute enormously to technological innovation and economic growth, research, and increased knowledge. Workers with S&E skills include technicians and technologists, researchers, educators, and managers. In addition, there are many others with S&E training who use their skills in a variety of nominally non-S&E occupations (such as writers, financial managers, paralegals) and many niches in the labor market where the need to interpret and use S&E knowledge is key.

Chapter Organization

This chapter has four major sections. First is a general profile of the S&E labor force. This includes the demographic characteristics (population size, gender, and race/ethnicity) of the S&E labor force. It also covers educational backgrounds, earnings, places of employment, occupations, and whether the S&E labor force makes use of S&E training. Much of the data in this section in available only through 1999 due to the temporary discontinuation of the National Survey of College Graduates (NSCG) of the National Science Foundation (NSF), which is the central part of NSF's Scientists and Engineers Statistical Data System (SESTAT) data system on scientists and engineers.[1]

Second is a look at the labor market conditions for recent S&E graduates—graduates whose labor market outcomes are most sensitive to labor market conditions. For recent S&E doctoral degree recipients, the special topics of academic employment and postdoctoral appointments (hereafter referred to by the colloquial term *postdocs*) are also examined.

Third is the age and retirement profile of the S&E labor force. This is key to gaining insights into the possible future structure and size of the S&E educated population.

The last section focuses on the global S&E labor force—both its growth abroad and the importance of the international migration of scientists and engineers to the United States and the world.

U.S. S&E Labor Force Profile

This section profiles the U.S. S&E labor force, providing specific information about its size, recent growth patterns, projected labor demand, and trends in sector of employment. It also looks at workers' use of their S&E training, educational background, and salaries.[2]

Section Overview

The S&E labor force includes both individuals in S&E occupations and many others with S&E training who may use their knowledge in a variety of different jobs. Employment in S&E occupations has grown rapidly over the past 2 decades and is currently projected to continue to grow faster than general employment through the next decade. Although most individuals with S&E degrees do not work in occupations with formal S&E titles, most of them, even at the bachelor's degree level, report doing work related to their degree even in mid- and late-career. Compared with the general labor force, S&E occupations generally have lower unemployment rates. However, the economic downturn that began in 2001 has caused S&E unemployment rates to rise faster than the national average, narrowing that gap. The proportion of women and ethnic minorities in the S&E labor force continues to grow but, with the exception of Asian/Pacific Islanders, remains smaller than their proportion of the overall population.

How Large Is the U.S. S&E Workforce?

Estimates of the size of the U.S. S&E workforce vary based on the criteria used to define *scientist* or *engineer*. Education, occupation, field of degree, and field of employment are all factors that may be considered.[3] (See sidebar, "Who Is a Scientist or an Engineer?" and appendix table 3-1.)

The size of the S&E workforce in 1999 (the most recent year for which both occupational and education information are available) varies between approximately 3 million and 10 million individuals, depending on the definition and perspective used. Although the Bureau of Labor Statistics' (BLS) Current Population Survey (CPS) counted 5.3

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[1] Budgetary considerations precluded conducting the 2001 National Survey of College Graduates (NSCG), which provides population estimates for approximately 85 percent of the science and engineering labor force within the Scientists and Engineers Statistical Data System (SESTAT). The NSCG is being restarted with a new sample in 2003.

[2] Much of the data in this section comes from SESTAT, a unified database that contains information on the employment, education, and demographic characteristics of scientists and engineers in the United States. The National Science Foundation, Division of Science Resources Statistics (NSF/SRS) derives SESTAT data from three of its surveys: the National Survey of College Graduates, the NSCG, and the Survey of Doctorate Recipients. Because the NSCG did not take place in 2001, SESTAT data is current only through 1999. (These surveys generally take place every 2 years.) NSF/SRS surveys U.S. residents who hold at least a bachelor's degree (in either an S&E or non-S&E field) and who, during the survey's reference period, were not institutionalized, were age 75 or younger, and either had trained or were working as a scientist or engineer. (That is, participants either had at least one bachelor's degree or higher in an S&E field, or had a bachelor's degree or higher in a non-S&E field and worked in an S&E occupation.) The 1999 SESTAT surveys used the week beginning April 15, 1999, as their reference period.

[3] For a detailed discussion of the S&E degree fields and occupations in SESTAT, see NSF/SRS 1999a. A list of S&E occupations and fields is contained in appendix table 3-1. In general, S&E occupations and fields in this report include individuals working in social sciences and exclude medical practitioners and technicians (including computer programmers). Thus, a physician with an M.D. will not be considered to be a scientist or engineer either by occupation or by highest degree, but is likely (but not certain) to be included in statistics that incorporate individuals with S&E degrees based on their field of bachelor's degree.

Who Is a Scientist or an Engineer?

The terms *scientist* and *engineer* have many definitions, none of them perfect. (For a more thorough discussion, see *SESTAT and NIOEM: Two Federal Databases Provide Complementary Information on the Science and Technology Labor Force* (NSF/SRS 1999b) and "Counting the S&E Workforce—It's Not That Easy" (NSF/SRS 1999a). This chapter uses multiple definitions for different analytic purposes; other reports use even more definitions. The three main definitions used in this chapter follow:

- **Occupation.** The most common way to count scientists and engineers in the workforce is to include individuals having an occupational classification that matches some list of science and engineering occupations. Although considerable questions can arise regarding how well individual write-ins or employer classifications are coded, the occupation classification comes closest to defining the work a person performs. (For example, an engineer by occupation may or may not have an engineering degree.) One limitation of classifying by occupation is that it will not capture individuals using S&E knowledge, sometimes extensively, under occupational titles such as manager, salesman, or writer.[*] It is common for persons with an S&E degree in such occupations to report that their work is closely related to their degree and, in many cases, to also report research and development as a major work activity.
- **Highest degree.** Another way to classify scientists and engineers is to focus on the field of their highest (or most recent) degree. For example, classifying as "chemist" a person who has a bachelor's degree in chemistry—but who works as a technical writer for a professional chemists' society magazine—may be appropriate. Using this "highest degree earned" classification does not solve all problems, however. For example, should a person with a bachelor's degree in biology and a master's degree in engineering be included among biologists or engineers? Should a person with a bachelor's degree in political science be counted among social scientists if he also has a law degree? Classifying by highest degree earned in situations similar to the above examples may be appropriate, but one may be uncomfortable excluding an individual who has both a bachelor's degree in engineering and a master's degree in business administration from an S&E workforce analysis.
- **Anyone with an S&E degree or occupation.** Classification by both occupation and education is another approach. NSF's sample surveys of scientists and engineers attempt to include U.S. residents who either have an S&E degree or an S&E occupation.[†]

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[*] For example, in most collections of occupation data a generic classification of postsecondary teacher fails to properly classify many university professors who would otherwise be included by most definitions of the S&E workforce. The Scientists and Engineers Statistical Data System (SESTAT) data mostly avoids this problem through use of a different survey question, coding rules, and respondent followups.

[†] Individuals who lacked U.S. S&E degrees but who earned S&E degrees in another country are included in 1999 SESTAT data to the extent that they were in the United States in 1990, as were individuals who had at least bachelor's degrees in some non-S&E field and who were working in S&E occupations in 1993.

million individuals in S&E occupations, a separate NSF survey found 3.3 million holders of S&E degrees in S&E occupations (table 3-1 and BLS 2001). This difference may reflect the inclusion of both individuals employed in S&E occupations who did not earn at least a bachelor's degree and individuals with non-S&E degrees; it may also partially stem from other technical differences between the surveys.

In 1999, 10.5 million employed individuals had at least one degree in an S&E field. This broader definition of the S&E workforce relates to many of the ways science and technical knowledge is used in the United States.

Table 3-1
Measures of S&E workforce: 1999

Measure and degree status	Workforce
BLS Current Population Survey	
All employed in S&E	5,294,000
With bachelor's degree or higher	4,021,000
SESTAT data system	
Employed S&E degree holders	10,480,000
In S&E occupation	3,259,000

BLS Bureau of Labor Statistics

SOURCES: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999; and National Bureau of Economic Research's Merged Outgoing Rotation Group Files from the Bureau of Labor Statistics' Current Population Survey.

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S&E Workforce Growth

Despite some limitations in measuring the S&E labor force, occupation classifications allow examination of growth in at least one measure of scientists and engineers over extended periods. Using data from the decennial census, the number of college graduates working in narrowly defined S&E occupations (excluding technicians and computer programmers) and employed outside academia increased by 159 percent between 1980 and 2000, to a total of 3.6 million jobs in 2000 (figure 3-1).[4] This represents a 4.9

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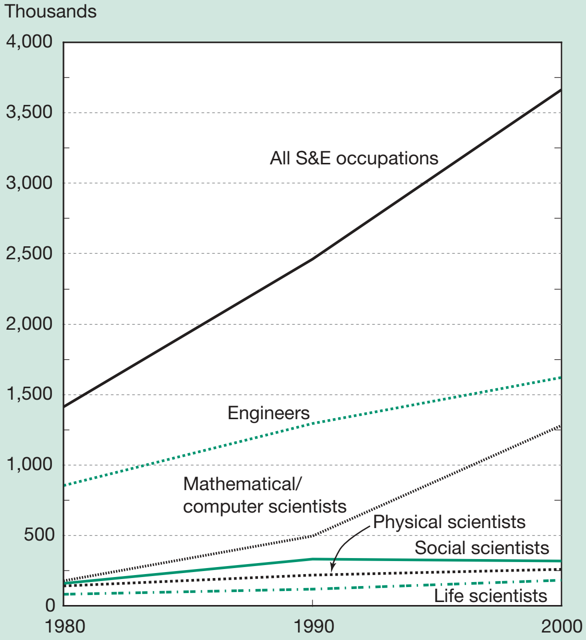
[4] Another difficulty when using occupation to identify scientists and engineers in many data sources other than SESTAT is that many workers in academia are identified by occupational titles that do not indicate academic specialty. For that reason, the time trend examined here is only for individuals outside academic employment.

Figure 3-1
College graduates in nonacademic S&E occupations, by occupation: 1980, 1990, and 2000



SOURCES: U.S. Decennial Census Public Use Microdata Samples, 1980 and 1990; and National Bureau of Economic Research's Merged Outgoing Rotation Group files from the Bureau of Labor Statistics' Current Population Survey. See appendix table 3-2.

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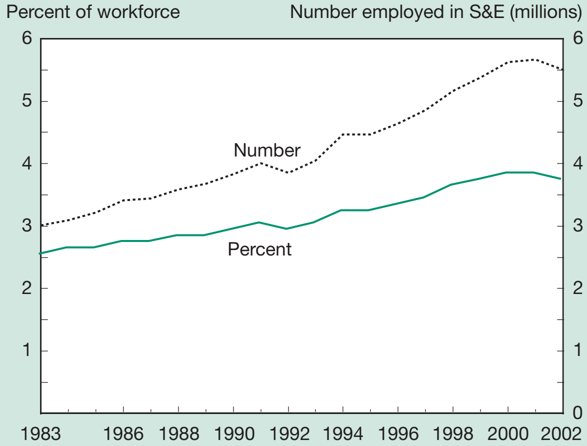
percent average annual growth rate, much more than the 1.1 percent average annual growth rate of the entire labor force.

Although every broad S&E occupational group grew between 1980 and 2000 (the lowest growth, 81 percent, occurred in physical sciences), the most explosive growth was in mathematics and computer sciences, which experienced a 623 percent increase (177,000 jobs in 1980 compared with 1.28 million jobs in 2000).

Using data from the monthly CPS from 1993 to 2002 to look at employment in S&E occupations across all sectors and education levels creates a very similar view, albeit with some significant differences. The 3.1 average annual growth rate in all S&E employment is almost triple the rate for the general workforce. This is reflected in the growing proportion of total jobs in S&E occupations, which increased from 2.6 percent in 1983 to 3.8 percent in 2002. Also noteworthy are the decreases in employment in S&E occupations between 1991 and 1992 and between 2001 and 2002—evidence that S&E employment is not exempt from economic downturns (figure 3-2).

Figure 3-2
U.S. workforce in S&E occupations: 1983–2002



SOURCES: U.S. Decennial Census Public Use Microdata Samples, 1980 and 1990; and National Bureau of Economic Research's Merged Outgoing Rotation Group files from the Bureau of Labor Statistics' Current Population Survey. See appendix table 3-3.

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Projected Demand for S&E Workers

The most recent occupational projections from the BLS, for the period from 2000–10, predict that employment in S&E occupations will increase about three times faster than the overall growth rate for all occupations (table 3-2). (Although BLS made these projections before the most recent economic downturn, they may still be indicative of long-term trends.) The economy as a whole is expected to provide approximately 15 percent more jobs over this decade, with employment opportunities for S&E jobs expected to increase by 2.2 million jobs, or about 47 percent (BLS 2001).

Approximately 86 percent of the projected increase in S&E jobs is in computer-related occupations. Indeed, without computer and mathematical occupations, the projected growth in S&E occupational employment would be just slightly more than overall employment growth (figure 3-3). The number of jobs for computer software engineers is expected to increase from 697,000 to 1.4 million and employment for computer systems analysts is expected to grow from 431,000 to 689,000 jobs.

Within engineering occupations, environmental engineering is projected to have the biggest relative employment gains, increasing by 14,000 jobs or about 27 percent. Computer hardware engineering is also expected to experience above-average employment gains, growing by 25 percent. Employment for all engineering occupations is expected to increase by less than 10 percent.

Projected job opportunities in life science occupations will grow by almost 18 percent (33,000 new jobs) from 2000 to 2010. At 27 percent (10,000 new jobs), medical science occupations will experience the largest predicted growth. BLS expects employment in physical science occupations to increase by about 18 percent (from 239,000 to 283,000 jobs), with slightly less than half of these projected job gains for environmental scientists (21,000 new jobs).

Finally, predictions indicate that social science occupations will experience above-average growth of 20 percent, largely due to the employment increases anticipated for market and survey researchers (27 percent or 30,000 new jobs).

Table 3-2
Total S&E jobs: 2000 and projected 2010
(Thousands)

Occupation	2000	2010	Change
All occupations	145,571	167,754	22,183
All S&E occupations	4,706	6,904	2,197
Scientists	3,241	5,301	2,059
Life scientists	184	218	33
Mathematical/computer scientists	2,408	4,308	1,900
Computer specialists	2,318	4,213	1,895
Mathematical scientists	89	95	5
Physical scientists	239	283	44
Social scientists	410	492	82
Engineers	1,465	1,603	138

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Office of Occupational Statistics and Employment Projections. See appendix table 3-4.

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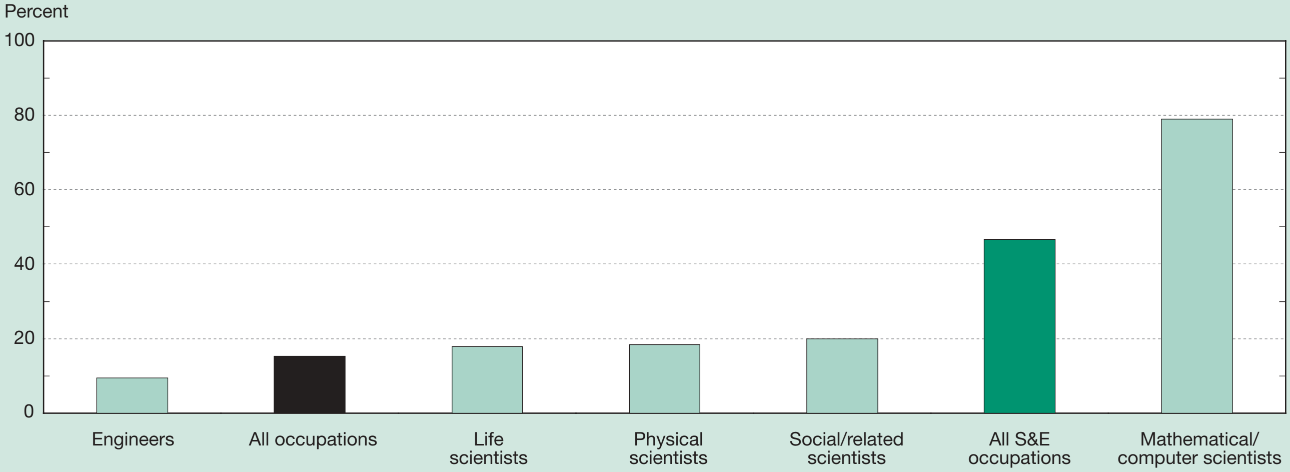
Figure 3-3
Projected increase in employment, by occupation: 2000–10



SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Office of Occupational Statistics and Employment Projections. See appendix table 3-4.

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How Are People With an S&E Education Employed?

Although the majority of S&E degree holders do not work in S&E occupations, this does not mean they do not use their S&E training. In 1999, of the 5 million individuals whose highest degree was in a S&E field and who did not work in S&E occupations, 67 percent indicated that they worked in a job at least somewhat related to the field of their highest S&E degree (table 3-3).[5] According to 1999 SESTAT data, almost 80 percent of individuals whose highest degree earned was in mathematics or computer sciences and who worked in non-S&E jobs reported working in fields related to their degree, compared with 63 percent of individuals whose highest degree earned was in social or physical sciences.

Of all employed individuals whose highest degree was in S&E, 77 percent reported their jobs as at least somewhat related to the fields of their highest degree and 46 percent reported their jobs as closely related to their field (appendix tables 3-5 and 3-6).[6] In the 1–4-year period after receiving their degrees, 73 percent of S&E doctorate holders say that they have jobs closely related to the degrees they received compared with 68 percent of master's degree recipients and 42 percent of bachelor's degree recipients (figure 3-4). This relative ordering of relatedness by level of degree holds

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[5] Because this question asked only about the field of an individual's highest degree, it is not possible to evaluate the science and engineering content of jobs held by S&E degree holders with non-S&E advanced degrees, such as MBAs and M.D.s.

[6] Although self-assessments by survey respondents are highly subjective, they may capture associations between training and scientific expertise not evident through occupational classifications. For example, an individual with an engineering degree, but with an occupational title of salesman, may still use or develop technology.

Table 3-3
S&E degree holders employed in non-S&E occupations, by highest degree and relation of degree to job: 1999

Highest degree	Degree holders	Degree related to job: Closely	Degree related to job: Somewhat	Degree related to job: Not
	Number	Percent		
All degrees[a]	4,976,900	33.2	34.1	32.7
Bachelor's	4,092,800	29.9	34.7	35.5
Master's	724,800	48.7	31.2	20.1
Doctoral	155,200	46.0	35.6	18.5

[a] Includes professional degrees.

NOTE: Details may not add to totals because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999.

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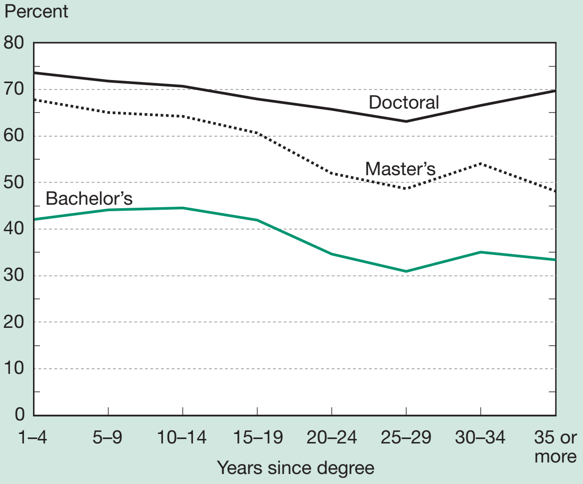
Figure 3-4
S&E degree holders employed in jobs closely related to highest degree, by highest degree and years since degree: 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT),1999. See appendix table 3-6.

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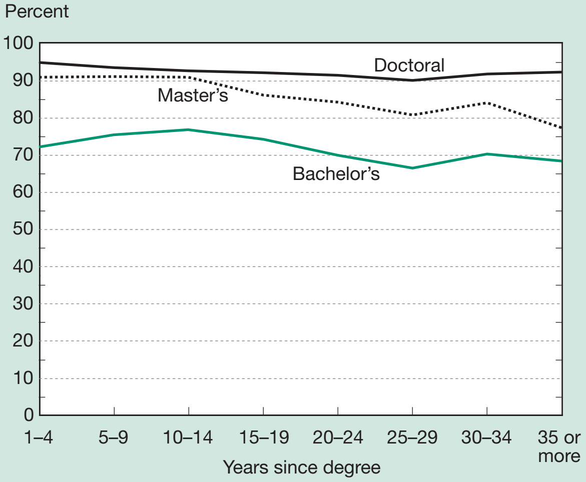
across all periods of years since recipients received their degrees. However, at every degree level, the relatedness of job to degrees falls with time since degree.[7] There are many good reasons for this trend: individuals may change their career interests over time, gain skills in different areas while working, take on general management responsibilities, and forget some of their original college training (or some of their original college training may become obsolete). Given these possibilities, the career-cycle decline in the relevance of an S&E degree is only modest. When a somewhat weaker criterion is used—are jobs "closely" or "somewhat" related to an individual's field of highest degree—even higher proportions of S&E graduates report their jobs being related to their degrees. Over 70 percent of S&E bachelor's degree holders report their jobs at least somewhat related to their field of degree until 25–29 years after their degrees. Among S&E doctorate holders at any point in their careers, less than 10 percent report their jobs as not related to their field of degree (figure 3-5).

Figure 3-6 shows differences in the percentages of individuals who reported their job as closely related to their field of degree, by major S&E disciplines for bachelor's degree holders. Although mathematics and computer sciences often are combined into a single group, figure 3-6 shows them

Figure 3-5
S&E highest degree holders employed in jobs closely or somewhat related to highest degree, by years since degree: 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT),1999. See appendix table 3-5.

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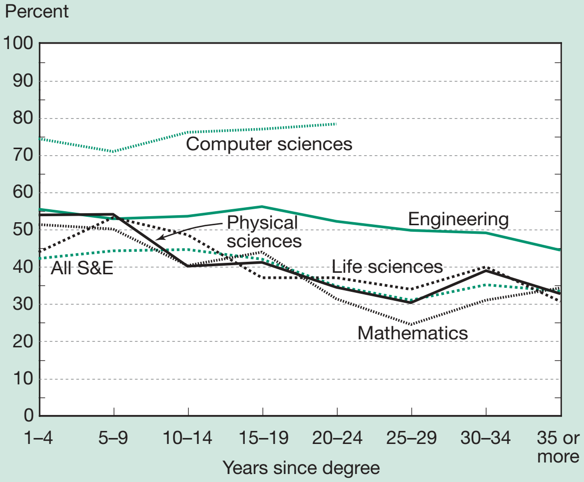
[7] The only exception is for doctorate holders who earned their degrees more than 25 years ago, where the percentage of individuals holding jobs closely related to their degrees actually increased. This may reflect differences in retirement rates.

Figure 3-6
S&E bachelor's degree holders employed in jobs closely related to degree, by field and years since degree: 1999



NOTE: Computer science degrees were not awarded in significant numbers more than 25 years ago.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999. See appendix table 3-6.

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separately because of their differing patterns. From 1–4 years after receiving their degrees, the percentage of S&E bachelor's degree holders who reported their jobs as closely related to their field of degree ranged from 30 percent for individuals with degrees in social sciences to 74 percent for individuals with degrees in computer sciences. Between these extremes, most other S&E fields show similar percentages for recent graduates: 55 percent for engineering, 54 percent for physical sciences, 52 percent for mathematics, and 44 percent for life sciences.

Employment in Non-S&E Occupations

About 5 million S&E degree holders worked in non-S&E occupations in 1999. Slightly more than half held management or administrative positions (28 percent), sales and marketing jobs (15 percent), or K–12 teaching posts (9 percent). About 89 percent of non-S&E K–12 teachers reported their work as at least somewhat related to their S&E degree compared with approximately 73 percent of managers and administrators and 51 percent of individuals holding sales and marketing jobs (table 3-4).

About 83 percent of the 5 million S&E degree holders not working in S&E occupations in 1999 reported their highest degree as a bachelor's degree; 15 percent listed a master's degree; and 3 percent, a doctorate. Among individuals with a bachelor's degree, approximately two-thirds reported their jobs as closely or somewhat related to their field of highest degree compared with four-fifths of S&E doctoral degree recipients and master's degree recipients (table 3-3).

Employment in S&E Occupations

Because S&E knowledge is used so widely across so many different jobs, a count of individuals in S&E occupations is one of the narrowest definitions of the S&E labor force. Of the nearly 8 million individuals in the labor force in 1999 whose highest degree earned was in an S&E field, slightly more than one-third (3 million) worked in S&E occupations. In addition, 2.5 million people who had received training in S&E disciplines, but whose highest degree was in a non-S&E field, were employed in S&E occupations. Another 282,000 college-educated individuals were employed in S&E occupations but did not hold a degree in an S&E field (table 3-5).

Table 3-4
Individuals with S&E highest degree employed in non-S&E occupations, by occupation and relation of degree to job: 1999

		Degree related to job		
Occupation	Degree holders	Closely	Somewhat	Not
	Number	Percent		
All non-S&E occupations	4,976,900	33.2	34.1	32.7
Managers/administrators	1,416,000	30.0	43.0	27.0
Sales/marketing	764,400	13.3	37.5	49.2
K–12 teachers	452,400	65.8	22.7	11.5
Technologists/technicians	337,600	46.6	34.1	19.3
Health related	322,200	58.1	27.1	14.7
Social services	291,500	61.2	28.7	10.0
Arts/humanities	122,500	21.7	38.1	40.2
Non-S&E postsecondary teachers	50,000	68.1	23.7	8.2
Other	1,220,400	20.0	29.2	50.8

NOTE: Details may not add to totals because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999.

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Table 3-5

College-educated individuals with S&E degrees or S&E occupations, by S&E employment status and field of highest degree: 1999

Degree status	All occupations	S&E occupations	Non-S&E occupations
All college educated	10,761,800	3,540,800	7,221,000
No S&E degree in S&E occupation	282,000	282,000	na
S&E degree	10,479,800	3,258,800	7,221,000
S&E highest degree	7,980,000	3,003,200	4,976,800
Engineering	1,936,400	1,303,300	633,100
Life and related sciences	1,287,700	361,700	926,000
Mathematics/computer sciences	1,045,800	537,200	508,600
Physical and related sciences	621,700	343,000	278,700
Social and related sciences	3,088,400	458,000	2,630,400
Non-S&E highest degree	2,499,800	255,600	2,244,200

na not applicable

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999.

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Table 3-6

Individuals in S&E occupations, by highest degree: 1999

(Percent distribution)

Occupation	All degrees	Bachelor's	Master's	Doctoral	Professional
All S&E occupations	100.0	100.0	100.0	100.0	100.0
Engineers	38.7	45.5	36.5	17.4	7.2
Life and related scientists	9.7	6.8	7.0	25.0	42.2
Mathematical/computer scientists	33.0	37.1	34.3	13.9	18.8
Physical and related scientists	8.4	7.0	7.1	17.5	1.4
Social and related scientists	10.3	3.6	15.1	26.2	30.4

NOTE: Percents may not sum to 100 because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999.

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Altogether, approximately 3.5 million individuals with S&E degrees worked in S&E occupations in 1999 (appendix table 3-7). Engineers represented 39 percent (1.37 million), and computer scientists and mathematicians, 33 percent (1.17 million). Physical scientists accounted for less than 9 percent.

By subfield, electrical engineers made up about one-fourth (362,300) of all individuals employed as engineers, whereas biologists accounted for about three-fifths (206,500) of employment in life sciences. In physical and social science occupations, chemistry (121,700) and psychology (197,000), respectively, were the largest occupational subfields.

Approximately 56 percent of individuals employed in S&E occupations reported a bachelor's degree as their highest degree earned, whereas about 29 percent listed a master's degree and 14 percent, a doctorate. Almost half of bachelor's degree recipients were engineers; slightly more than one-third were computer scientists and mathematicians. These occupations were also the most prominent among individuals with master's degrees, at approximately 37 and 34 percent, respectively (table 3-6).

Unemployment

A two-decades long view of unemployment trends in S&E occupations, regardless of education level, comes from the CPS data for 1983–2002.[8] During this 20-year period, the unemployment rate for all individuals in S&E occupations ranged from a low of 1.4 percent in 1999 to a high of 3.9 percent in 2002. Overall, the S&E occupational unemployment rate was both lower and less volatile than either the rate for all U.S. workers (ranging from 3.9 to 9.9 percent) or for S&E technicians (ranging from 2.0 to 6.1 percent). During the period, computer programmers had a similar unemployment rate compared with the rate for all S&E occupations, but greater volatility (ranging from 1.2 to 6.5 percent). The most recent recession in 2002 appears to have had a strong impact on S&E employment, with the differential between S&E and general unemployment falling to only 1.9

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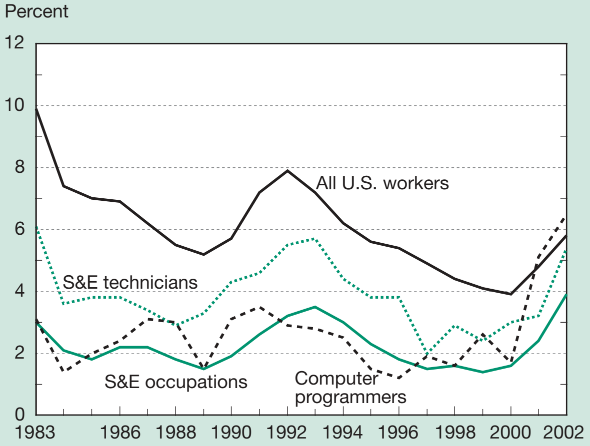
[8] To maximize annual sample size from the Current Population Survey (CPS) without using multiple records for the same individuals (due to CPS' longitudinal sample design), only records from merged outgoing rotation groups were used. This may result in slightly different unemployment estimates than would be derived from an average of monthly unemployment.

Figure 3-7
Unemployment rate, by occupation: 1983–2002



SOURCES: U.S. Decennial Census Public Use Microdata Samples, 1980 and 1990; and National Bureau of Economic Research's Merged Outgoing Rotation Group files from the Bureau of Labor Statistics' Current Population Survey. See appendix table 3-8.

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percentage points, compared with 6.9 percentage points in 1983 (figure 3-7).[9] This may be due to the unusually strong reductions in research and development in the information and related technology sectors (see chapter 4).

The 1999 unemployment rate among the approximately 3.5 million college-educated individuals with S&E occupations in the labor force reached only 1.6 percent, or 56,000 individuals, compared with 4.4 percent for the U.S. labor force as a whole and 1.9 percent for all professional specialty workers (table 3-7).[10] Unemployment for college graduates working in S&E occupations dropped steadily from 1993, when it stood at 2.6 percent, to 1999. In the latter year, physical scientists had the highest unemployment rate (1.9 percent), and computer scientists and mathematicians, the lowest (1.2 percent). By degree level, 1.6 percent of S&E bachelor's degree recipients and master's degree recipients were unemployed, compared with 1.2 percent of doctorate holders.

Table 3-7
Unemployment rate for individuals in S&E occupations: 1993 and 1999
(Percent)

Occupation	1993	1999
All S&E occupations	2.6	1.6
Engineers	3.4	1.8
Life and related scientists	1.7	1.3
Mathematical/computer scientists	1.9	1.2
Physical and related scientists	2.8	1.9
Social and related scientists	1.6	1.4

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1993 and 1999. See appendix table 3-7.

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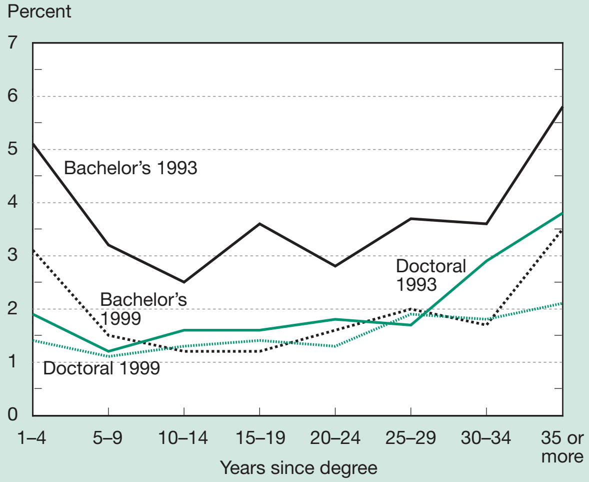
Figure 3-8 compares unemployment rates over career cycles for bachelor's degree holders and doctorate holders in 1993 and in 1999. Looking at field of degree rather than occupation includes both individuals who might have left an S&E occupation for negative economic reasons and individuals who moved into other careers due to more positive factors. The generally stronger 1999 labor market had its greatest effect on bachelor's degree holders: for individuals at every point in their careers, the unemployment rate dropped by about 2 percentage points between 1993 and 1999. Although labor market conditions had a lesser effect on doctorate holders' unemployment rates, significant reductions in unemployment rates between 1993 and 1999 did occur for those individuals at both the beginning and the end of their careers.

Similarly, labor market conditions from 1993 to 1999 had a greater effect on the portion of bachelor's degree holders who said they were working involuntarily out of the field (IOF) of their highest degree than on doctorate holders (figure 3-9). However, the greatest differences in IOF rates for bachelor's degree holders occurred not at the beginning and end of their careers, but in midcareer. For doctorate holders, IOF rates changed little either between 1993 and 1999 or throughout most of their careers. The decline in IOF rates for the oldest doctorate holders may partially reflect lower

Figure 3-8
Unemployment rate for S&E highest degree holders, by years since degree: 1993 and 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1993 and 1999.

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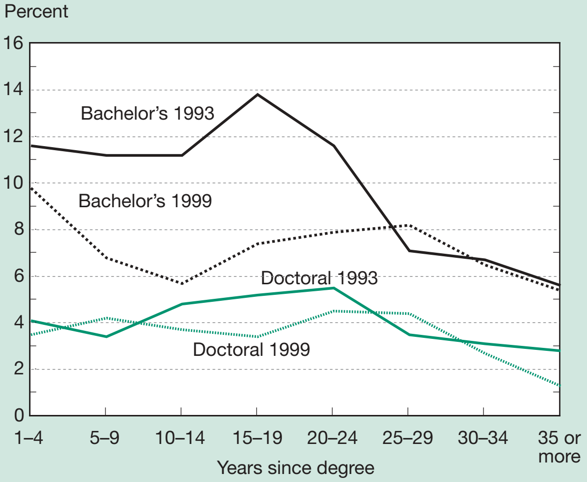
[9] A large part of the narrowing of this difference is due to the general decline in unemployment over this period.

[10] The unemployment rate is the ratio of individuals who are unemployed and seeking employment to the total labor force (i.e., those who are employed plus those who are unemployed and seeking employment). Individuals not in the labor force (i.e., individuals who are unemployed and not seeking employment) are excluded from the denominator.

Figure 3-9
Involuntarily-out-of-field rate of S&E highest degree holders, by years since degree: 1993 and 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1993 and 1999.

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retirement rates for individuals working in their fields. Taken together with the unemployment patterns shown in figure 3-8, this finding implies that more highly educated S&E workers are less vulnerable to changes in economic conditions than individuals who hold only bachelor's degrees.

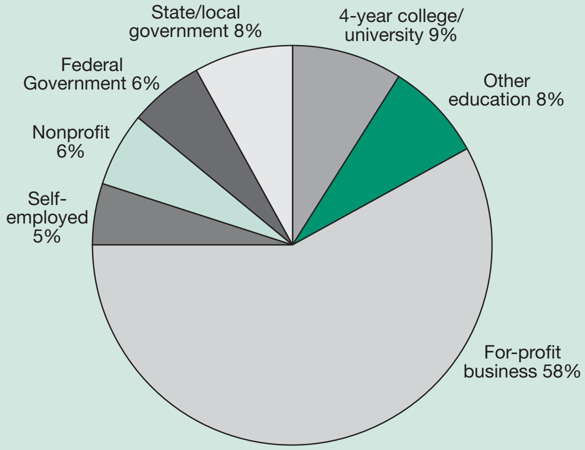
Employment Sectors

The private, for-profit sector is by far the largest provider of S&E employment. In 1999, approximately 73 percent of individuals working as scientists and engineers who had bachelor's degrees and 62 percent of persons who had master's degrees worked for private, for-profit companies. However, the majority of individuals with doctorates (51 percent) worked in the academic sector. Sectors that employ fewer S&E workers include educational institutions other than 4-year colleges and universities, nonprofit organizations, and state or local government agencies (appendix table 3-9).

The percentage of scientists and engineers employed in private, for-profit industry varies greatly for different S&E occupations. Although slightly more than three-fourths of both mathematical/computer scientists and engineers (76 and 78 percent, respectively) worked in this sector in 1999, only about one-fourth (27 percent) of life scientists and one-fifth (19 percent) of social scientists did so. Educational institutions employed the largest percentages of life scientists (48 percent) and social scientists (45 percent) (appendix table 3-9). (See sidebar, "Educational Distribution of S&E Workers.")

A similar pattern appears when looking at S&E degree holders, regardless of whether they work in S&E occupations (figures 3-10 and 3-11). For-profit business employs 58 percent of all individuals whose highest degree is in S&E, including 34 percent of S&E doctorate holders. Four-year colleges and universities are a more important employer for S&E doctorate holders (42 percent). However, it should be noted that this figure includes a variety of employment types other than tenure track; only 27.6 percent of S&E doctorate holders in the labor force are employed in tenured or tenure-track positions (See sidebar, "Who Performs Research and Development?")

Figure 3-10
Employment sector of S&E degree holders: 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999. See appendix table 3-11.

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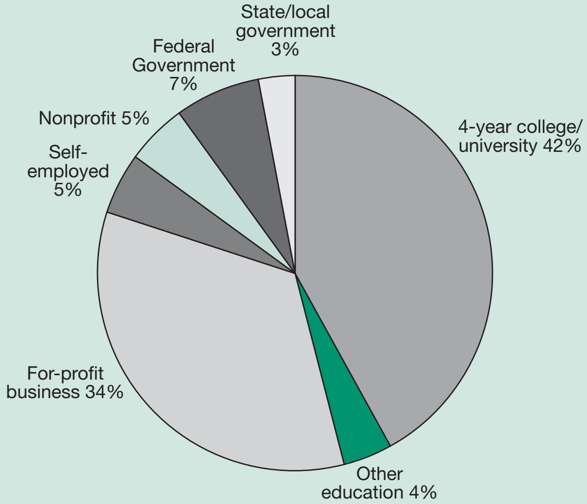
Figure 3-11
Employment sector of S&E doctorate holders: 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999. See appendix table 3-11.

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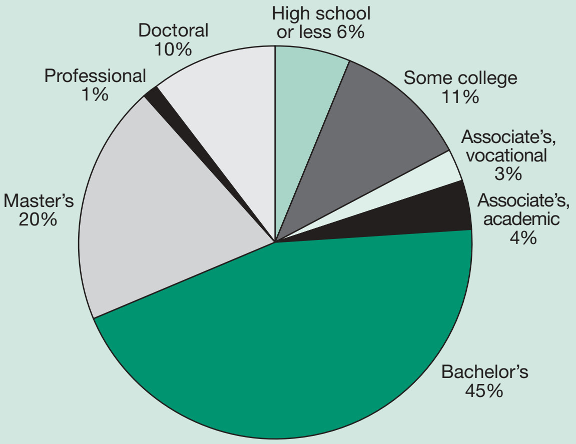
Educational Distribution of S&E Workers

Discussions of the science and engineering workforce often focus on individuals who hold doctorates. However, Current Population Survey data on the educational achievement of individuals working in S&E occupations outside academia in 2000 indicate that only 10.9 percent had doctorates (figure 3-12). In 2000, more than two-thirds of individuals working in nonacademic S&E occupations had bachelor's degrees (47 percent) or master's degrees (21 percent).

Figure 3-12
Educational distribution of individuals in nonacademic S&E occupations: 2000



SOURCE: U.S. Bureau of the Census, Current Population Survey, 2000.

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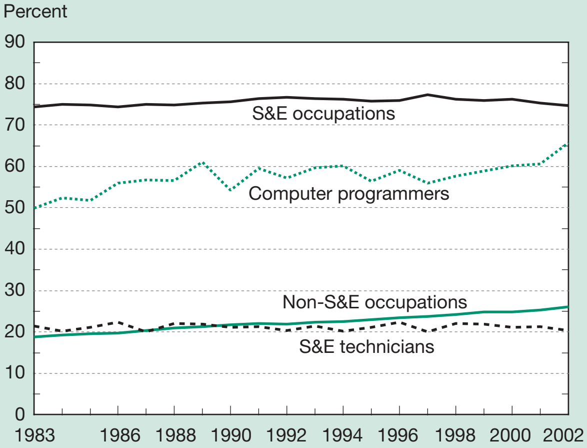
Almost one-fourth of individuals working in S&E occupations had not earned a bachelor's degree. Although technical issues of occupational classification may account for the size of the nonbaccalaureate S&E workforce, it is also true that many individuals who have not earned a bachelor's degree do enter the labor force with marketable technical skills from technical or vocational school training (with or without earned associate's degrees), college courses, and on-the-job training. In information technology, and to some extent in other occupations, employers frequently use certification exams, without reference to formal degrees, to judge skills.

From 1983 to 2002, the proportion of individuals in the S&E workforce without college degrees remained relatively constant. Among individuals working in S&E technician occupations the proportion with college degrees also remained nearly constant, at approximately 21 percent. In contrast, the proportion of individuals with college degrees among all workers in non-S&E occupations rose from 19 to 26 percent. The occupation of computer programmer, a non-S&E occupation of particular interest in discussions of the S&E labor force, increased its percentage of individuals with college degrees from 50 to 66 percent (figure 3-13).

Figure 3-13
Individuals with at least bachelor's degree, by selected occupation: 1983–2002



NOTE: Data before 1992 are based on individuals who had at least 16 years of education.

SOURCES: U.S. Decennial Census Public Use Microdata Samples, 1980 and 1990; National Bureau of Economic Research's Merged Outgoing Rotation Group files from the Bureau of Labor Statistics' Current Population Survey. See appendix table 3-10.

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Salaries

In 1999, bachelor's degree holders employed in S&E occupations had a median annual salary of $59,000; master's degree holders, $64,000; and doctorate holders, $68,000 (table 3-8 and appendix table 3-12).

From 1993 to 1999, median salaries for individuals employed in S&E occupations rose about 25 percent in current dollars. Computer scientists and mathematicians experienced the largest salary growth (37 percent), followed by engineers (30 percent). By degree level, median salaries for bachelor's degree recipients rose by 31 percent, followed by master's degree recipients at 28 percent.

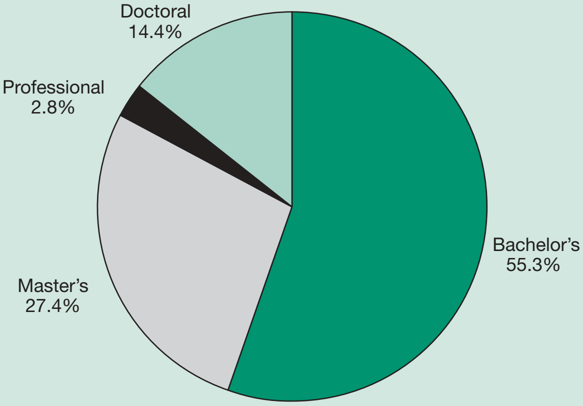
Education produces far more dramatic effects on the "tails" of the distribution (the proportion with either very high or very low earnings) than on median earnings. In 1999, 5 percent of S&E bachelor's degree holders had salaries greater than $100,000, compared with 16 percent of doctorate holders. Similarly, 21 percent of bachelor's degree holders earned less than $30,000, compared with 5 percent of doctorate holders. The latter figure is inflated due to the inclusion of postdocs. (The Survey of Doctorate Recipients defines postdoc as a temporary position awarded in academia, industry, or government for the primary purpose of receiving additional research training.)

Who Performs Research and Development?

Although individuals with science and engineering degrees use their acquired knowledge in various ways (e.g., teaching, writing, evaluating, and testing), they show a special interest in research and development. Figure 3-14 shows the distribution of individuals with S&E degrees by level of degree who report R&D as a major work activity (defined as the activity involving the greatest, or second greatest, number of work hours from a list of 22 possible work activities). Individuals with doctorates constitute only 6 percent of all individuals with S&E degrees but represent 14.4 percent of individuals who report R&D as a major work activity. However, the majority of S&E degree holders who report R&D as a major work activity have only bachelor's degrees (55.3 percent). An additional 27.4 percent have master's degrees and 2.8 percent have professional degrees, mostly in medicine. Figure 3-15 shows the distribution of individuals with S&E degrees, by field of highest degree, who reported R&D as a major work activity. Individuals with engineering degrees constitute almost one-third (31.7 percent) of the total. Note that 17.9 percent did not earn their highest degrees in S&E fields; in most cases, a person in this group has an S&E bachelor's degree and a higher degree in a professional field such as business, medicine, or law.

Figure 3-16 shows the percentages of S&E doctorate holders reporting R&D as a major work activity by field of degree and by years since receipt of doctorate. Individuals working in physical sciences and engineering report the highest R&D rates over their career cycles, with the lowest R&D rates in social sciences. Although the percentage of doctorate holders engaged in R&D activities declines as time since receipt of degree increases, it remains greater than 50 percent in all fields except social sciences up to 25 years since receipt of degree. This decline may reflect a normal career process of movement into management or other career interests. It may also reflect, even within nonmanagement positions, increased opportunity and the ability of more experienced scientists to perform functions involving the interpretation and use, as opposed to the creation of, scientific knowledge.

Figure 3-14
Distribution of S&E-degreed workers with R&D as major work activity, by degree level: 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999.

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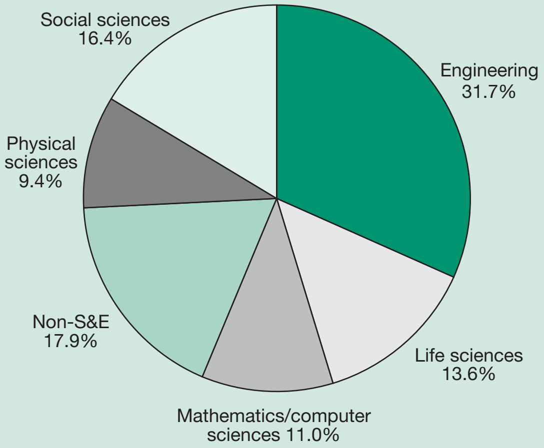
Figure 3-15
Distribution of S&E-degreed workers with R&D as major work activity, by field of highest degree: 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT),1999.

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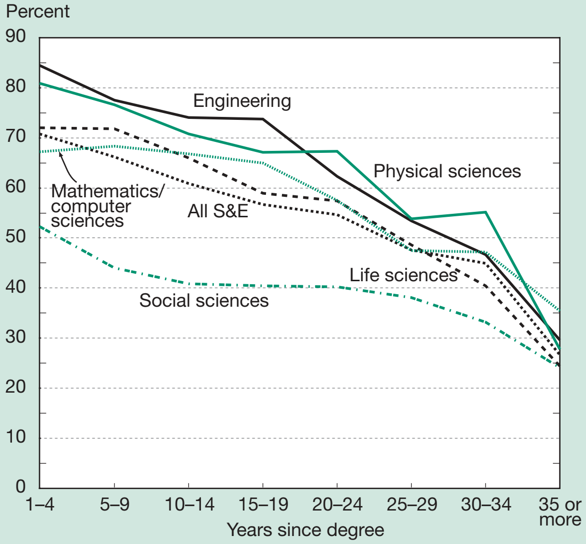
Figure 3-16
S&E doctorate holders engaged in R&D as major work activity, by field and years since degree: 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999.

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Table 3-8
Median annual salary of U.S. individuals in S&E occupations, by highest degree: Selected years, 1993–99
(Dollars)

Highest degree	1993	1995	1997	1999
All S&E	48,000	50,000	55,000	60,000
Bachelor's	45,000	48,000	52,000	59,000
Master's	50,000	53,500	59,000	64,000
Doctoral	55,000	58,000	62,000	68,000

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1993–99. See appendix table 3-12.

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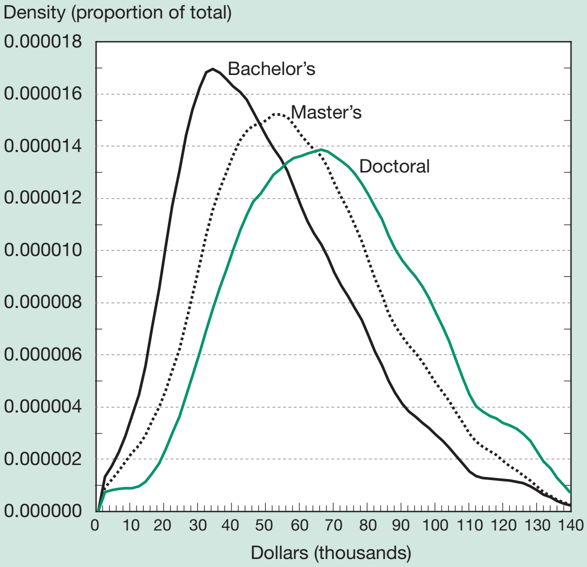
Figure 3-17
Salary distribution of S&E degree holders employed full time, by degree level: 1999



NOTE: Salary distribution is smoothed using kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999.

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Figure 3-17 illustrates the distribution of salaries earned by individuals with S&E degrees.

Women and Minorities in S&E

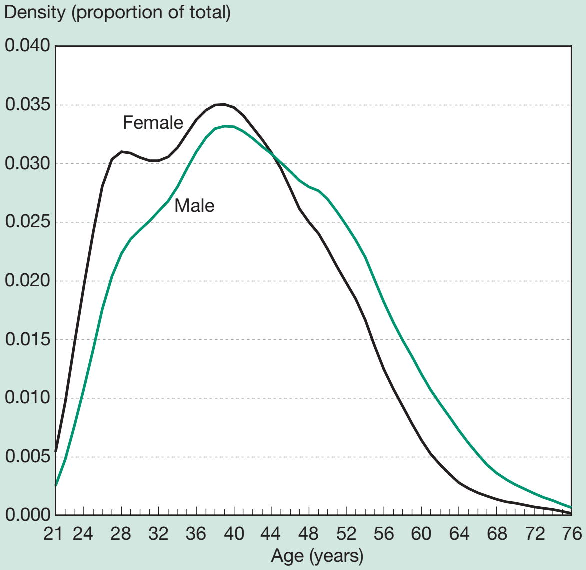
Demographic factors for women and minorities (such as age and years in the workforce, field of S&E employment, and highest degree level achieved) influence employment patterns. Demographically, men differ from women, and minorities differ from nonminorities; thus, their employment patterns also are likely to differ. For example, because larger numbers of women and minorities entered S&E fields only recently, women and minority men generally are younger than non-Hispanic white males and have fewer years of experience (appendix table 3-13). Age and stage in career in turn influence such employment-related factors as salary, position, tenure, and work activity. In addition, employment patterns vary by field (see sidebar, "Growth of Representation of Women, Minorities, and the Foreign Born in S&E Occupations") and these differences influence S&E employment, unemployment, salaries, and work activities. Highest degree earned, yet another important influence, particularly affects primary work activity and salary.

Representation of Women in S&E

Women constituted almost one-fourth (24.7 percent) of the college-educated workforce in S&E occupations but close to half (46 percent) of the total U.S. workforce in 1999. Although changes in the NSF/SRS surveys do not permit analysis of long-term trends in employment, short-term trends indicate an increase in female doctorate holders employed in S&E. In 1993, women constituted 20 percent of doctorate holders in S&E occupations in the United States; in 1995, 22 percent; in 1997, 23 percent; and in 1999, 24 percent.

Age Distribution and Experience. Differences in age and related time spent in the workforce account for many of the differences in employment characteristics between men and women. On average, women in the S&E workforce are younger than men (figure 3-18): 50 percent of women and 36 percent of men employed as scientists and engineers in 1999 received their degrees within the past 10 years. The difference is even more profound at the doctorate level,

Figure 3-18
Age distribution of individuals in S&E occupations, by sex: 1999



NOTE: Age distribution is smoothed using kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999.

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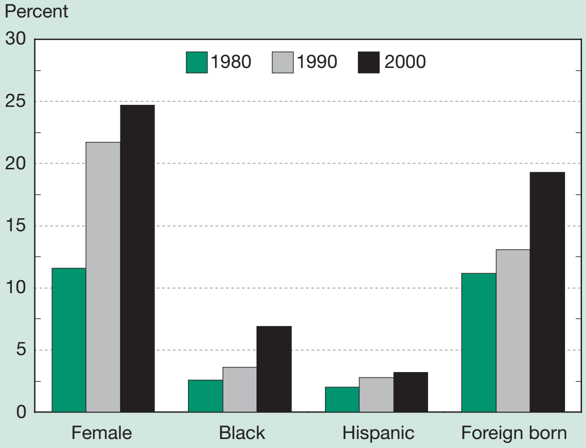
Growth of Representation of Women, Minorities, and the Foreign Born in S&E Occupations

A longer view of changes in the sex and ethnic composition of the science and engineering workforce can be achieved by examining data on college-educated individuals in nonacademic S&E occupations from the 1980 Census, the 1990 Census, and the March 2000 Current Population Survey (figure 3-19). In 2000, the percentage of historically underrepresented groups in S&E occupations remained lower than the percentage of those groups in the total college-educated workforce:

- Women made up 24.7 percent of the S&E workforce and 48.6 percent of the college-degreed workforce.
- Blacks made up 6.9 percent of the S&E workforce and 7.4 percent of the college-degreed workforce.
- Hispanics made up 3.2 percent of the S&E workforce and 4.3 percent of the college-degreed workforce.

However, since 1980, share of S&E occupations has more than doubled for blacks (2.6 to 6.9 percent) and women (11.6 to 24.7 percent). Hispanic representation also increased between 1980 and 2000, albeit at a lower rate (2.0 to 3.2 percent). The percentage of foreign-born college graduates in S&E jobs increased from 11.2 percent in 1980 to 19.3 percent in 2000.

Figure 3-19
College graduates in nonacademic S&E occupations, by sex and race/ethnicity: 1980, 1990, and 2000



SOURCES: U.S. Decennial Census Public Use Microdata Samples, 1980 and 1990; and National Bureau of Economic Research's Merged Outgoing Rotation Group files from the Bureau of Labor Statistics' Current Population Survey.

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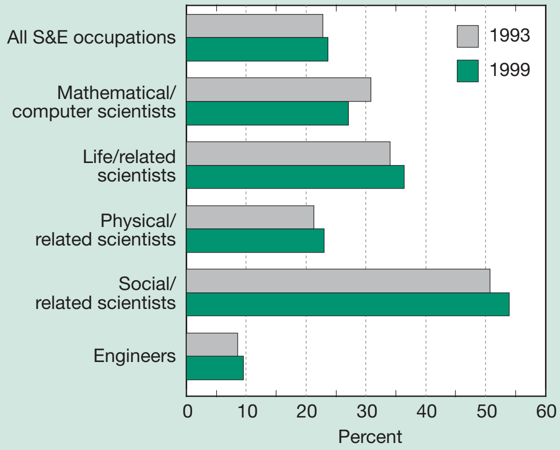
where there is a much greater concentration of female doctorate holders in their late thirties. One clear consequence of this age distribution is that a much larger proportion of male scientists and engineers at all degree levels, but particularly at the doctorate level, will reach traditional retirement age during the next decade. This alone will have a significant effect upon gender ratios, and also perhaps on the numbers of female scientists in positions of authority as the large proportion of female doctorate holders in their late thirties moves into their forties.

S&E Occupation. Representation of men and women also differs according to field of occupation. For example, in 1999, women constituted 54 percent of social scientists, compared with 23 percent of physical scientists and 10 percent of engineers (figure 3-20). Within engineering, female representation is greater in some fields than in others. For example, women constituted 15 percent of chemical and industrial engineers, but only 6 percent of aerospace, electrical, and mechanical engineers. Since 1993, the percentage of women in most S&E occupations has gradually increased. However, in mathematics and computer sciences, the percentage of women declined about 4 percentage points between 1993 and 1999 (figure 3-20 and appendix table 3-13).

Educational Background. In many occupational fields, male scientists generally have higher education levels than female scientists. In the science workforce as a whole, 16 percent of women and 20 percent of men have achieved doctorate degrees. In biology, those figures stand at 26 percent of women and 40 percent of men; in chemistry, 14 percent of women and 27 percent of men; and in psychology, 22 percent of women and 42 percent of men. Engineering figures, however, differ much less, as about 5 percent of women and 6 percent of men have doctorates (NSF/SRS 1999c). Differences

Figure 3-20
Female employment in S&E occupations, by broad occupation: 1993 and 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1993 and 1999. See appendix table 3-13.

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in highest degree achieved influence differences in type of work performed, employment in S&E jobs, and salaries.

Labor Force Participation, Employment, and Unemployment. Male scientists and engineers are more likely to be in the labor force, employed full time, and/or employed in their field of highest degree. Women are more likely to be out of the labor force, employed part time, and/or employed involuntarily outside their fields (IOF). Many of these differences are due to differences in age distributions of men and women.

Unemployment rates for men and women in S&E occupations were similar in 1999: 1.5 percent of men and 1.8 percent of women were unemployed. By comparison, the unemployment rate in 1993 was 2.8 percent for men and 2.2 percent for women (table 3-9 and appendix table 3-14)

Salaries. In 1999, female scientists and engineers earned a median annual salary of $50,000, about 22 percent less than the median annual salary earned by male scientists and engineers ($64,000). Between 1993 and 1999, median annual salaries for female scientists and engineers increased by 25 percent, compared with an increase of 28 percent for their male counterparts (table 3-10). Several factors may contribute to these salary differentials. Women more often work in educational institutions, in social science occupations, and in nonmanagerial positions; they also tend to have less experience. In 1999, among scientists and engineers in the workforce who have held their degrees for 5 years or less, women earned an average median annual salary that was 83 percent of that earned by men.

Salary differentials varied by broad field. In computer sciences and mathematics occupations in 1999, women earned approximately 12 percent less than men; in life science occupations, the difference stood at 23 percent. Women also earned their highest and lowest median salaries in those two occupation groups, $58,000 in computer sciences and mathematics and $39,000 in life sciences (figure 3-21 and appendix table 3-15).

Table 3-9
Unemployment rate for individuals in S&E occupations, by sex and race/ethnicity: 1993 and 1999
(Percent)

Sex or race/ethnicity	1993	1999
All with S&E occupations	2.6	1.6
Male	2.7	1.5
Female	2.1	1.8
White	2.4	1.5
Asian/Pacific Islander	4.0	1.5
Black	2.8	2.6
Hispanic	3.5	1.8

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1993 and 1999. See appendix table 3-14.

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Table 3-10
Median annual salary of individuals employed in S&E occupations, by sex and race/ethnicity: Selected years, 1993–99
(Dollars)

Sex or race/ethnicity	1993	1995	1997	1999
All with S&E occupations	48,000	50,000	55,000	60,000
Male	50,000	52,000	58,000	64,000
Female	40,000	42,000	47,000	50,000
White	48,000	50,500	55,000	61,000
Asian/Pacific Islander	48,000	50,000	55,000	62,000
Black	40,000	45,000	48,000	53,000
Hispanic	43,000	47,000	50,000	55,000

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1993–99. See appendix table 3-15.

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Representation of Racial and Ethnic Minorities in S&E

With the exception of Asian/Pacific Islanders, minorities represent only a small proportion of scientists and engineers in the United States.[11] (Although Asian/Pacific Islanders constitute only 4 percent of the U.S. population, they accounted for 11 percent of scientists and engineers in 1999.) Collectively, blacks, Hispanics, and other ethnic groups (the latter includes American Indian/Alaskan Natives) constituted 24 percent of the total U.S. population and 7 percent of the total S&E workforce in 1999.[12] Blacks and Hispanics each accounted for about 3 percent of scientists and engineers, and other ethnic groups represented less than 0.5 percent (appendix table 3-16). Between 1993 and 1999, the portion of Asian/Pacific Islanders in the S&E workforce increased by about 2 percentage points, whereas the portion of blacks, Hispanics, and other ethnic groups did not change significantly.

Age Distribution. As in the case of women, underrepresented racial and ethnic minorities are much younger than non-Hispanic whites in the same S&E occupations (figure 3-22), and this is even truer for doctorate holders in S&E occupations. In the near future, a much greater proportion of non-Hispanic white doctorate holders in S&E occupations will be reaching traditional retirement ages compared

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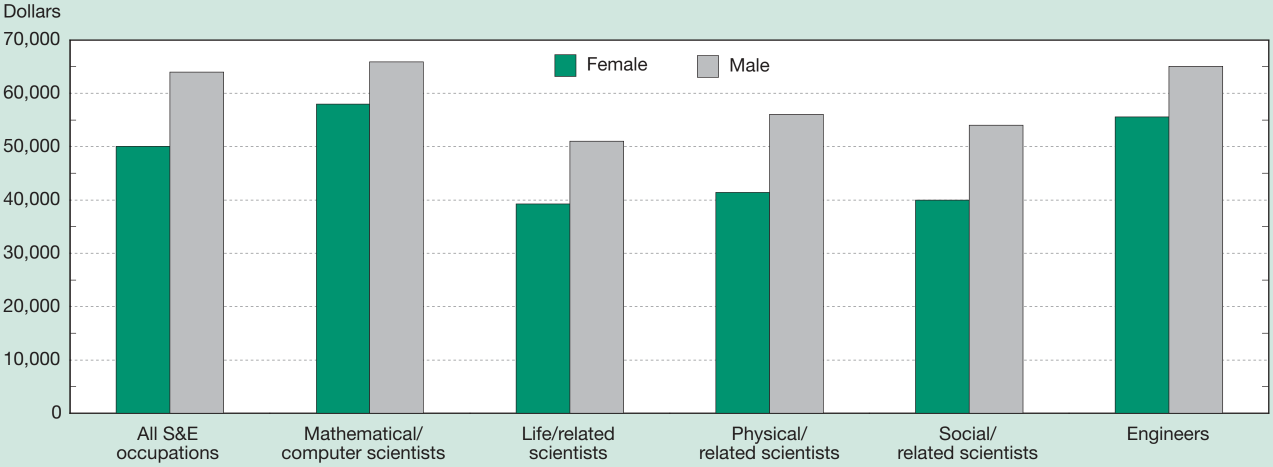
[11] The term *underrepresented minorities* includes three groups that have a smaller representation in science and engineering than in the overall population: blacks, Hispanics, and American Indian/Alaskan Natives. (In accordance with Office of Management and Budget guidelines, the racial and ethnic groups described in this section are identified as white and non-Hispanic, Asian/Pacific Islander, black and non-Hispanic, Hispanic, and American Indian/Alaskan Native.)

[12] The S&E fields in which blacks, Hispanics, and American Indian/Alaskan Natives earn their degrees influence their participation in the S&E labor force. Disproportionately more blacks, Hispanics, and American Indian/Alaskan Natives earn degrees in social sciences and work in social service positions (such as social worker and clinical psychologist), which the NSF/SRS defines as non-S&E occupations. See NSF/SRS 1999a and appendix table 3-1 for the NSF/SRS classification of S&E fields.

Figure 3-21
Median annual salary of employed scientists and engineers, by broad occupation and sex: 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999. See appendix table 3-15.

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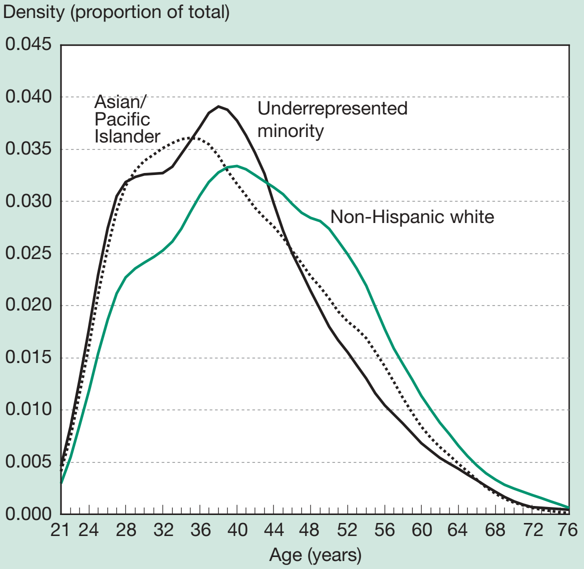
Figure 3-22
Age distribution of individuals in S&E occupations, by race/ethnicity: 1999



NOTE: Age distribution is smoothed using kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999.

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with underrepresented racial and ethnic doctorate holders. Indeed, unlike the distribution of ages of male and female doctorate holders shown in figure 3-18, figure 3-22 shows that the slope of the right-hand side of the age distribution is far steeper for non-Hispanic whites. This implies a more rapid increase in the numbers retiring or otherwise leaving S&E employment. It should also be noted that Asian/Pacific Islander doctorate holders in S&E occupations (measured by race and not by place of birth) are on average the youngest racial/ethnic group.

S&E Occupation. Asian/Pacific Islander, black, and American Indian/Alaskan Native scientists and engineers tend to work in different fields than their white and Hispanic counterparts. Fewer Asian/Pacific Islanders work in social sciences than in other fields. In 1999, they constituted 4 percent of social scientists, but more than 11 percent of engineers and more than 13 percent of individuals working in mathematics and computer sciences. More black scientists and engineers work in social sciences and in computer sciences and mathematics than in other fields. In 1999, blacks constituted approximately 5 percent of social scientists, 4 percent of computer scientists and mathematicians, 3 percent of physical scientists and engineers, and 2 percent of life scientists. Other ethnic groups (which includes American Indian/Alaskan Natives) work predominantly in social and life sciences, accounting for 0.4 percent of social and life scientists and 0.3 percent or less of scientists in other fields in 1999. Hispanics appear to have a more even representation across all fields, constituting approximately 2.5 to 4.5 percent of scientists and engineers in each field (appendix table 3-13).

Educational Background. The educational achievement of scientists and engineers also differs among racial and ethnic groups. A bachelor's degree is more likely to be the highest degree achieved for black and Hispanic scientists and engineers than for white or Asian/Pacific Islander scientists and engineers—in 1999, a bachelor's degree was the highest degree achieved for 61 percent of black scientists and engineers in the U.S. workforce compared with 56 percent of all scientists and engineers (appendix table 3-13).

Labor Force Participation, Employment, and Unemployment. Labor force participation rates vary by race and ethnicity. Minority scientists and engineers are more likely than others to be in the labor force (either employed or seeking employment). In 1999, participation rates in the labor force ranged between 87 and 93 percent for Asian/Pacific Islander, black, Hispanic, and American Indian/Alaskan Native scientists and engineers, compared with 86 percent for white scientists and engineers (appendix table 3-14). Age and related retirement rates may contribute to these differences. On average, white scientists and engineers are older than scientists and engineers in other racial and ethnic groups: 28 percent of white scientists and engineers were age 50 or older in 1999, compared with 15–20 percent of Asian/Pacific Islanders, blacks, and Hispanics (appendix table 3-13). For individuals in similar age groups, the labor force participation rates of white and minority scientists and engineers are similar.

Although more minority individuals remain in the labor force, they also are more likely to be unemployed. In 1999, the unemployment rate of white scientists and engineers was somewhat lower than the rate for other racial and ethnic groups. The unemployment rate for both whites and Asian/Pacific Islanders stood at 1.5 percent, compared with 1.8 percent for Hispanics and 2.6 percent for blacks. In 1993, the unemployment rate for whites reached 2.4 percent, compared with 4.0 percent for Asian/Pacific Islanders, 3.5 percent for Hispanics, and 2.7 percent for blacks (table 3-9).

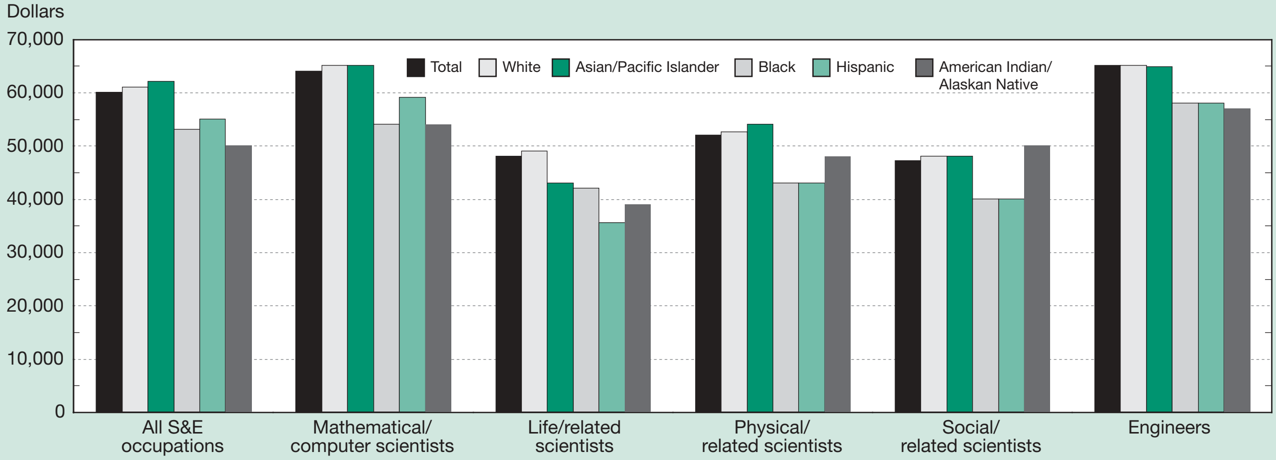
The differences in 1999 unemployment rates are evident within S&E fields as well as for S&E as a whole. For example, the unemployment rate for white engineers was 1.8 percent; for black and Asian/Pacific Islander engineers, it was 2.3 and 1.8 percent, respectively (appendix table 3-14).

Salaries. Salaries for individuals in S&E occupations vary among the different racial and ethnic groups. In 1999, white and Asian/Pacific Islanders in S&E occupations earned similar median annual salaries of $61,000 and $62,000, respectively, compared with $55,000 for Hispanics, $53,000 for blacks, and $50,000 for other ethnic groups, including American Indian/Alaskan Natives (figure 3-23 and table 3-10). These salary patterns are similar to rates recorded in 1993. However, age, field of degree, and sector of employment all influence differences.

Across occupational fields and age categories, the median annual salaries of individuals in S&E occupations by race and ethnicity do not follow a consistent pattern. For example, in 1999, the median annual salary of 20–29-year-old engineers with bachelor's degrees ranged from $35,000 for American Indian/Alaskan Natives to $46,000 for Hispanics. Among individuals between the ages of 40 and 49, the median salary ranged from $60,000 for Asian/Pacific Islanders and American Indian/Alaskan Natives to $70,000 for whites.

In 1999, the median annual salary of engineers with bachelor's degrees who had received their degrees within the past 5 years reached $45,000 for all ethnicities except individuals in the "other" category (including American Indian/Alaskan Natives) (appendix table 3-15). Among engineers who had received their degrees 20–24 years previously, the median annual salary reached approximately $70,000 for all ethnicities. (See sidebar, "Salary Differentials")

Figure 3-23
Median annual salary of scientists and engineers, by broad occupation and race/ethnicity: 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999. See appendix table 3-15.

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Salary Differentials

Differences in salaries of women and ethnic minorities are often used as indicators of progress that individuals in such groups are making in science and engineering. Indeed, as shown in table 3-11, these salary differences are substantial when comparing all individuals with S&E degrees by level of degree: in 1999, women with S&E bachelor's degrees had full-time mean salaries that were 35.1 percent less than those of men with S&E bachelor's degrees.[*] Blacks, Hispanics, and individuals in other underrepresented ethnic groups with S&E bachelor's degrees had full-time salaries that were 21.9 percent less than those of non-Hispanic whites and Asian/Pacific Islanders with S&E bachelor's degrees.[†] These raw differences in salary are lower but still large at the doctorate level (–25.8 percent for women and –12.7 percent for underrepresented ethnic groups). In contrast, foreign-born individuals with U.S. S&E degrees have slightly higher salaries than U.S. natives at the bachelor's and master's levels, but their salaries at the doctorate level show no statistically significant differences from those of natives.

Table 3-11
Estimated salary differentials of individuals with S&E degrees, by individual characteristics and degree level: 1999
(Percent)

Characteristic	Bachelor's	Master's	Doctoral
Female versus male	–35.1	–28.9	–25.8
Controlling for age and years since degree	–27.2	–25.5	–16.7
Plus field of degree	–14.0	–9.6	–10.3
Plus occupation and employer characteristics	–11.0	–8.0	–8.4
Plus family and personal characteristics	–10.2	–7.4	–7.4
Plus gender-specific marriage and child effects	–4.6	NS	–3.1
Black, Hispanic, and other versus white and Asian/Pacific Islander	–21.9	–19.3	–12.7
Controlling for age and years since degree	–13.0	–14.6	–4.7
Plus field of degree	–8.6	–6.7	–2.2
Plus occupation and employer characteristics	–7.3	–4.2	NS
Plus family and personal characteristics	–5.7	–3.3	NS
Foreign born with U.S. degree versus native born	3.7	9.5	NS
Controlling for age and years since degree	6.7	12.4	7.8
Plus field of degree	NS	NS	NS
Plus occupation and employer characteristics	NS	–2.8	–2.8
Plus family and personal characteristics	NS	–3.1	–2.7

NS not significantly different from zero at $p = .05$

NOTE: Linear regressions on ln(full-time annual salary).

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999.

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However, differences in average age, work experience, fields of degree, and other characteristics make direct comparison of salary and earnings statistics difficult. Generally, engineers earn a higher salary than social scientists, and newer employees earn less than those with more experience. One common statistical method that can be used to look simultaneously at salary and other differences is regression analysis.[‡] Table 3-11 shows estimates of salary differences for different groups after controlling for several individual characteristics.

Although this type of analysis can provide insight, it cannot give definitive answers to questions about the openness of S&E to women and minorities for many reasons. The most basic reason is that no labor force survey ever captures all information on individual skill sets, personal background and attributes, or other characteristics that may affect compensation. In addition, even characteristics that are measurable are not distributed randomly among individuals. An individual's choice of degree field and occupation, for example, will reflect in part the real and perceived opportunities for that individual. The associations of salary differences with individual characteristics, not field choice and occupation choice, are examined here.

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[*] For consistency with the other salary differences shown in table 3-11, these salary differences were generated from regressions of ln (full-time annual salary) on just a dummy variable for membership in the group being examined. This corresponds to differences in the geometric mean of salary, not to differences in median salary as reported elsewhere in this chapter.

[†] "Underrepresented ethnic group" as used here includes individuals who reported their race as black, Native American, or other, or who reported Hispanic ethnicity.

[‡] Specifically presented here are coefficients from linear regressions using the 1999 Scientists and Engineers Statistical Data System (SESTAT) data file of individual characteristics upon the natural log of reported full-time annual salary as of April 1999.

Effects of Age and Years Since Degree on Salary Differentials

Salary differences between men and women reflect to some extent the lower average ages of women with degrees in most S&E fields. Controlling for differences in age and years since degree reduces salary differentials for women compared with men by about one-fourth at the bachelor's degree level (to –27.2 percent) and by about one-third at the Ph.D. level (to –16.7 percent).[§]

When controlling for differences in age and years since degree, even larger drops in salary differentials are found for underrepresented ethnic minorities. Such controls reduce salary differentials of underrepresented minorities compared with non-Hispanic whites and Asian/Pacific Islanders by more than two-fifths at the bachelor's degree level (to –13.0 percent) and by nearly two-thirds at the doctorate level (to –4.7 percent).

Because foreign-born individuals in the labor force who have S&E degrees are somewhat younger on average than natives, controlling for age and years since degree moves their salary differentials in a positive direction—in this case, making an initial earnings advantage over natives even larger—to 6.7 percent for foreign-born individuals with S&E bachelor's degrees and to 7.8 percent for those with S&E doctorates.

Effects of Field of Degree on Salary Differentials

Controlling for field of degree and for age and years since degree reduces the estimated salary differentials for women with S&E degrees to –14.0 percent at the bachelor's level and to –10.3 percent at the doctorate level.[‖] These reductions generally reflect the greater concentration of women in the lower-paying social and life sciences as opposed to engineering and computer sciences. As noted above, this identifies only one factor associated with salary differences and does not speak to why there are differences between males and females in field of degree or whether salaries are affected by the percentage of women studying in each field.

Field of degree is also associated with significant estimated salary differentials for underrepresented ethnic groups. Controlling for field of degree further reduces salary differentials to –8.6 percent for those individuals with S&E bachelor's degrees and to –2.2 percent for those individuals with S&E doctorates. Thus, age, years since degree, and field of degree are associated with almost all doctorate-level salary differentials for underrepresented ethnic groups.

Compared with natives at any level of degree, foreign-born individuals with S&E degrees show no statistically significant salary differences when controlling for age, years since degree, and field of degree.

Effects of Occupation and Employer on Salary Differentials

Obviously, occupation and employer characteristics affect compensation.[#] Academic and nonprofit employers typically pay less for the same skills than employers pay in the private sector, and government compensation falls somewhere between the two groups. Other factors affecting salary are relation of work performed to degree earned, whether the person is working in S&E, whether the person is working in R&D, employer size, and U.S. region. However, occupation and employer characteristics may not be determined solely by individual choice, for they may also reflect in part an individual's career success.

When comparing women with men and underrepresented ethnic groups with non-Hispanic whites and Asian/Pacific Islanders, controlling for occupation and employer reduces salary differentials only slightly beyond what is found when controlling for age, years since degree, and field of degree. For foreign-born individuals compared with natives, controls for occupation and employer characteristics also produce only small changes in estimated salary differentials, but in this case, the controls result in small negative salary differentials at the master's (–2.8 percent) and doctorate (–2.8 percent) levels.

Effects of Family and Personal Characteristics on Salary Differentials

Marital status, children, parental education, and other personal characteristics are often associated with differences in compensation. Although these differences may indeed involve discrimination, they may also reflect many subtle individual differences that might affect work productivity.[**] As with occupation and employer characteristics, controlling for these characteristics changes salary differentials only slightly at any degree level. However, most of the remaining salary differentials for women disappear when the regression equations allow for the separate effects of marriage and children for each sex. Marriage is associated with higher salaries for both men and women, but has a larger positive association for men. Children have a positive association with salary for men but a negative association with salary for women.

[§] In the regression equation, this is the form: age, age^2, age^3, age^4; years since highest degree (YSD), YSD^2, YSD^3, YSD^4.

[‖] Included were 20 dummy variables for NSF/SRS SESTAT field-of-degree categories (out of 21 S&E fields; the excluded category in the regressions was "other social science").

[#] Variables added here include 34 SESTAT occupational groups (excluding "other non-S&E"), whether individuals said their jobs were closely related to their degrees, whether individuals worked in research and development, whether their employers had less than 100 employees, and their employers' U.S. Census region.

[**] Variables added here include dummy variables for marriage, number of children in the household younger than 18, whether the father had a bachelor's degree, whether either parent had a graduate degree, and citizenship. Also, sex, nativity, and ethnic minority variables are included in all regression equations.

Labor Market Conditions for Recent S&E Graduates

The labor market activities of recent S&E graduates often serve as the most sensitive indicators of changes in the S&E labor market. This section looks at a number of standard labor market indicators for bachelor's and master's degree recipients, and also examines a number of other indicators that may apply only to recent S&E doctorate-recipients.

In general, recent graduates in S&E fields found good labor market conditions during the periods for which NSF/SRS survey data exist (April 1999 for bachelor's degree recipients and master's degree recipients, and April 2001 for doctorate-recipients). Between 1999 and 2001, the proportion of recent S&E doctorate-recipients obtaining tenure-track positions increased slightly and the number of individuals entering postdocs decreased slightly. Despite these changes, only about one-fifth of S&E doctorate-recipients hold tenure-track positions 4–6 years after receiving their degrees.

Bachelor's and Master's Degree Recipients

Recent recipients of S&E bachelor's and master's degrees form an important component of the U.S. S&E workforce, accounting for almost half of the annual inflow into S&E occupations.[13] Recent graduates' career choices and entry into the labor market affect the supply and demand for scientists and engineers throughout the United States. This section offers insight into labor market conditions for recent S&E graduates in the United States. Topics examined include graduate school enrollment rates, employment by level and field of degree, employment sectors, and median annual salaries.

Relation of Employment to School

In 1999, approximately one-fifth of 1997 and 1998 graduates who had earned either bachelor's or master's degrees were enrolled full time in school at some level. Students who had majored in physical and life sciences were more likely to be full-time students than were graduates with degrees in computer and information sciences and engineering (appendix table 3-17).

Relation of Employment to Level and Field of Degree

Job market success varies significantly by level and field of degree. Finding employment directly related to field of study serves as one measure of success. In 1999, over half of employed master's degree recipients but only one-fifth of employed bachelor's degree recipients worked in jobs closely related to the field of their highest degree. Among both master's and bachelor's degree recipients, more students who had received their degrees in either engineering or computer sciences and mathematics worked in their field of study compared with individuals who received degrees in other S&E fields, whereas students who had received degrees in social sciences were less likely than their counterparts in other S&E fields to have jobs directly related to their degrees.

Employment Sectors

The private, for-profit sector employs the majority of recent S&E bachelor's and master's degree recipients (table 3-12). In 1999, 63 percent of bachelor's degree recipients and 57 percent of master's degree recipients found employment with private, for-profit companies. The education sector employs the second largest group of recent S&E graduates and more master's degree recipients (12 percent) than bachelor's degree recipients (8 percent) found employment with 4-year colleges and universities. The Federal sector employed only 5 percent of recent S&E master's degree recipients and 4 percent of bachelor's degree recipients in 1999; more engineering graduates than science graduates found employment in the Federal sector. Other sectors that employed only small numbers of recent S&E graduates include educational institutions other than 4-year colleges and universities, nonprofit organizations, and state and local government agencies. Only very small percentages of engineering bachelor's and master's degree recipients (1 and 2 percent, respectively) were self-employed.

Employment and Career Paths

As one might expect, more S&E master's degree holders reported having a career-path job compared with S&E bachelor's degree holders. (*Career-path jobs* help graduates fulfill their future career plans.) Approximately three-fourths of all master's degree recipients and three-fifths of all bachelor's degree recipients held a career-path job in 1999. Graduates with degrees in computer and information sciences or in engineering were more likely to hold career-path jobs compared with graduates with degrees in other fields: about four-fifths of recent bachelor's and master's degree graduates in computer and information sciences and in engineering reported that they held career-path jobs.

Salaries

In 1999, recent (1–3 years since degree) bachelor's degree recipients with degrees in computer and information sciences earned the highest median annual salaries ($44,000) among all recent science graduates. For recent graduates with degrees in engineering, individuals receiving degrees in electrical/electronics, computer, and communications engineering earned the highest median annual salaries ($46,000). The same pattern held true for recent master's degree recipients: individuals receiving degrees in computer and information sciences earned the highest median annual salaries ($58,000) among science graduates. Among

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[13] Much of the data for this section comes from the National Survey of Recent College Graduates. This survey collected information on the 1999 workforce status of 1997 and 1998 bachelor's and master's degree recipients in S&E fields. NSF/SRS has sponsored surveys of recent S&E graduates biennially since 1978.

Table 3-12
1997 and 1998 S&E bachelor's and master's degree recipients, by degree field and employment sector: 1999

		Employment sector						
		Education		Noneducation				
Degree and field	Employed	4-year college/ university	Other institution	Private for-profit company	Self-employed	Nonprofit organization	Federal Government	State/local government
	Thousands	Percent						
Bachelor's	539.2	8	10	63	1	7	4	7
Sciences	442.4	9	12	58	2	9	4	8
Engineering	96.7	4	1	86	<1	1	5	4
Master's	118.1	12	9	57	2	7	5	7
Sciences	80.6	15	12	48	3	10	4	9
Engineering	37.6	8	<1	78	1	1	8	4

NOTES: Employment sector refers to respondent's primary job on April 15, 1999. In this categorization, those working in 4-year colleges and universities or university-affiliated medical schools or research organizations were classified as "4-year college/university." Those working in elementary, middle, secondary, or 2-year colleges or other educational institutions were categorized as "other institution." Those reporting that they were self-employed but in an incorporated business were classified as "private for-profit company." For graduates with more than one eligible degree at the same level, the degree for which the graduate was sampled was used. Details may not add to totals because of rounding. Percents were calculated on nonrounded data.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Survey of Recent College Graduates, 1999.

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engineering graduates, individuals who received master's degrees in electrical/electronics, computer, and communications engineering earned the highest median annual salaries ($60,000) (appendix table 3-17).

Doctoral Degree Recipients

Analyses of labor market conditions for scientists and engineers holding doctorate degrees often focus on the ease or difficulty of beginning careers for recent doctoral degree recipients. Although a doctorate degree does create more career opportunities, both in terms of salary and type of employment, these opportunities come at the price of many years of foregone labor market earnings. Many doctorate holders also face an additional period of low earnings while completing a postdoc. In addition, some doctorate holders may not find themselves in the type of employment they desired while in graduate school.

Since the 1950s, the Federal Government has actively encouraged graduate training in S&E through numerous mechanisms. Ph.D. programs have served multiple facets of the national interest by providing a supply of more highly trained and motivated graduate students to aid university-based research. These programs have provided individuals with detailed, highly specialized training in particular areas of research, and paradoxically, through that same specialized training, generated a general ability to perform self-initiated research in more diverse areas.

The career aspirations of highly skilled individuals in general, and doctorate holders in particular, often cannot be measured through just salary and employment. Their technical and problem-solving skills make them highly employable, but they often attach great importance to the opportunity to do a type of work they care about and for which they have been trained. For that reason, no single measure can satisfactorily describe the doctoral S&E labor market. Some of the available labor market indicators, such as unemployment rates, IOF and in-field employment, satisfaction with field of study, employment in academia, postdocs, and salaries, are discussed below.

Aggregate measures of labor market conditions changed only slightly between 1999 and 2001 for recent (1–3 years after receipt of degree) S&E doctoral degree recipients. Unemployment rates for recent S&E doctoral degree recipients across all fields of study did not change significantly during that period (table 3-13). However, a smaller proportion of recent doctoral degree recipients reported working IOF (because jobs in their fields were not available) or involuntarily working part time; thus, the overall IOF rate decreased from 4.2 to 3.4 percent. However, these aggregate numbers mask numerous changes, both positive and negative, in many individual disciplines. In addition, IOF and unemployment rates in some fields moved in opposite directions.

Unemployment

Even for relatively good labor market conditions in the general economy, the 1.3 percent unemployment rate for recent S&E doctoral degree recipients as of April 2001 was very low; the April 2001 unemployment rate for all civilian workers was 4.4 percent and the rate for college graduates was 2.0 percent.[14] The highest unemployment rates were for recent doctoral degree recipients in civil engineering (3.5 percent), mechanical engineering (3.2 percent), and economics (2.2 percent).

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[14] People are said to be unemployed if they were not employed during the week of April 15, 1999, and had either looked for work during the preceding 4 weeks or were laid off from a job.

Table 3-13
Labor market rate for recent doctorate recipients 1–3 years after receiving doctorate, by field: 1999 and 2001
(Percent)

Doctorate field	Unemployment rate 1999	Unemployment rate 2001	Involuntarily out-of-field rate 1999	Involuntarily out-of-field rate 2001
All S&E fields	1.2	1.3	4.2	3.4
Engineering	0.9	1.8	2.7	1.7
Chemical	1.7	1.6	1.8	2.0
Civil	1.5	3.5	0.0	3.6
Electrical	0.7	0.9	2.5	1.5
Mechanical	0.3	3.2	3.2	1.7
Life sciences	1.1	1.1	2.5	2.5
Agriculture	0.0	0.3	3.1	4.1
Biological sciences	1.3	1.0	2.5	2.4
Mathematics/computer sciences	0.8	0.3	4.1	2.4
Computer sciences	0.9	0.4	1.8	2.3
Mathematics	0.7	0.3	6.2	2.4
Physical sciences	0.4	1.3	6.6	5.0
Chemistry	0.5	0.8	2.4	3.2
Geosciences	1.2	1.9	9.4	3.0
Physics and astronomy	0.0	1.9	11.1	8.2
Social sciences	2.1	1.3	5.7	5.1
Economics	0.5	2.2	4.2	2.1
Political science	3.4	0.8	11.6	8.7
Psychology	1.0	1.4	3.5	3.8
Sociology and anthropology	1.6	1.2	11.9	6.3

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 1999 and 2001.

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Involuntarily Working Outside Field

Another 3.4 percent of recent S&E doctoral degree recipients in the labor force reported in 2001 that they could not find (if they were seeking) full-time employment that was "closely related" or "somewhat related" to their degrees—a small decrease from 4.2 percent in 1999.[15] Although this measure is more subjective than the unemployment rate, the IOF rate often proves to be a more sensitive indicator of labor market difficulties for a highly educated and employable population. However, it is best to use both IOF rate and unemployment rate as measures of two different forms of labor market distress.

The highest IOF rates were found for recent doctoral degree recipients in political science (8.7 percent), physics and astronomy (8.2 percent), and sociology and anthropology (6.3 percent). However, in every case, these rates represented a drop from even higher rates in 1999. The lowest IOF rates were found in electrical engineering (1.5 percent), mechanical engineering (1.7 percent), and economics (2.1 percent).

Tenure-Track Positions

Most S&E doctorate holders ultimately do not work in academia and this has been true in most S&E fields for several decades (see chapter 5). In 2001, among S&E Ph.D. holders who received their degree 4–6 years previously, 19.2 percent were in tenure-track or tenured positions at 4-year institutions of higher education (table 3-14). Across fields, rates of tenure program academic employment for individuals who had received their degree 4–6 years previously ranged from 4.3 percent in chemical engineering to 44.1 percent in sociology and anthropology. Among Ph.D. holders who received their degree 1–3 years previously, only 16.2 percent were in tenure programs; this rate reflects the increasing use of postdocs by recent doctoral degree recipients in many fields. Between 1999 and 2001, a paradoxical pattern occurred: the proportion of the most recent doctoral degree recipients in tenure-track positions increased (although it remained below 1993 levels), but members of the group who received their degree 4–6 years previously showed a continued decline.

Although S&E doctorate holders must consider academia just one possible sector of employment, the availability of tenure-track positions is an important aspect of the job market for individuals who seek academic careers. A decrease in the rate of tenure-track employment for individuals who received their degree 4–6 years previously, from 26.6 percent in 1993 to 19.2 percent in 2001, reflects the availability both of tenure-track job opportunities in academia and of alternative employment opportunities. For example, one of the largest declines in tenure-track employment occurred in computer sciences, from 51.5 percent in 1993 to 23.6 percent in 2001.

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[15] Individuals counted as involuntarily out of field if they said they were working in jobs not related to their degree because no jobs in their field were available or if they were working part time because they could not find full-time work in their field.

Table 3-14
Doctorate recipients holding tenure and tenure-track appointments at 4-year institutions, by years since receipt of doctorate: 1993, 1999, and 2001
(Percent)

	1993		1999		2001	
Doctorate field	1–3 years	4–6 years	1–3 years	4–6 years	1–3 years	4–6 years
All S&E fields	18.4	26.6	13.7	22.2	16.2	19.2
Engineering	16.0	24.6	7.3	15.2	11.4	10.4
Chemical	8.1	14.0	2.4	6.5	5.8	4.3
Civil	24.7	27.1	20.3	33.6	18.8	21.7
Electrical	17.6	26.9	3.7	11.9	9.5	8.2
Mechanical	13.5	29.5	6.4	15.1	9.9	9.3
Life sciences	12.6	24.8	11.3	21.8	12.6	18.2
Agriculture	15.6	27.0	13.6	23.3	23.7	12.8
Biological sciences	12.1	24.8	10.9	22.0	11.3	18.3
Mathematics/computer sciences	39.7	54.1	20.8	36.7	22.5	26.6
Computer sciences	37.1	51.5	20.3	31.6	19.2	23.6
Mathematics	41.8	56.0	21.3	41.0	25.0	29.3
Physical sciences	9.7	18.2	8.1	15.2	10.2	14.9
Chemistry	7.7	16.3	9.4	14.2	10.2	11.5
Geosciences	12.7	26.2	14.3	24.0	17.7	25.4
Physics and astronomy	12.0	17.7	3.5	12.0	7.8	11.4
Social sciences	26.4	29.2	24.0	28.7	25.9	28.3
Economics	46.6	48.6	30.4	34.3	37.1	28.6
Political science	53.9	47.1	37.3	50.7	45.0	40.0
Psychology	12.7	15.5	14.9	16.0	14.8	19.3
Sociology and anthropology	37.9	46.9	33.4	43.4	41.3	44.1

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 1993, 1999, and 2001.

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Other measures of labor market distress in this field are low and computer science departments report difficulties recruiting faculty. The attractiveness of other areas of employment may also explain drops in tenure program rates for several engineering disciplines. However, it is less likely to explain smaller but steady drops in tenure program employment rates in fields that show other measures of distress, such as physics (with an IOF rate of 8.2 percent) and biological sciences (which has low unemployment and IOF rates, but shows other indications of labor market distress such as low salaries). Between 1993 and 2001, only psychology registered an increase in tenure program rates for individuals who received their doctorate 4–6 years previously, improving from 15.5 percent to 19.3 percent.

Relation of Occupation to Field of Degree

By strict definition of occupational titles, 16.9 percent of employed recent doctoral degree recipients worked in occupations outside S&E, often in administrative or management functions. However, when asked if their jobs related to their highest degree achieved, only 2.8 percent of recent doctoral degree recipients employed in non-S&E occupations reported that their jobs did not relate to their degree (table 3-15). By field, the percentages working in occupations not related to S&E ranged from 1.6 percent in computer sciences and mathematics to 3.6 percent in physical sciences. However, the 24.7 percent of recent doctoral degree recipients in physical sciences and the 22.8 percent of recent doctoral degree recipients in engineering working in other S&E fields may be more noteworthy. Figures show that 10.1 percent of recent doctoral degree recipients in physical sciences were working in life science occupations, and 15.8 percent of recent engineering doctoral degree recipients in computer sciences and mathematics (table 3-15).

Postdocs

The definition of postdocs differs among the academic disciplines, universities, and sectors that employ them, and these differences in usage probably affect self-reporting of postdoc status in the Survey of Recent Doctorate Recipients. Researchers often analyze data on postdoc appointments for recent doctoral degree recipients in relation to recent labor market issues. Although some of these individuals do want to receive more training in research, others may accept temporary (and usually lower-paying) postdoc positions because of a lack of permanent jobs in their field.

Science and Engineering Indicators – 1998 (NSB 1998) included an analysis of a one-time postdoc module from the 1995 Survey of Doctorate Recipients. This analysis showed a slow increase in the use of postdocs in many disciplines over time. (This rate was measured cross-sectionally by looking at the percentage of individuals in each graduation cohort who reported ever holding a postdoc position.) In addition, in physics and biological sciences (the fields with the most

Table 3-15
Scientists and engineers recently awarded doctorates, by degree field and relation to occupation: 2001
(Percent)

Doctorate field	Occupation relation to degree: Same field	Other S&E	Related non-S&E	Nonrelated non-S&E
Engineering	68.9	22.8	6.2	2.1
Life sciences	67.7	8.4	21.1	2.8
Mathematics/computer sciences	86.3	3.1	9.0	1.6
Social sciences	72.3	7.3	17.2	3.2
Physical sciences	64.5	24.7	7.2	3.6

NOTE: Percents may not sum to 100 because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2001.

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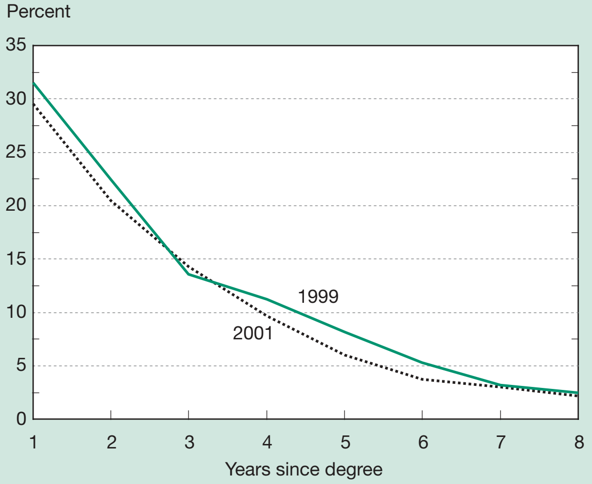
use of postdocs), median time spent in postdocs extended well beyond the 1–2 years found in most other fields.

Compared with 1999, data from 2001 show a small decline in the percentage of recent S&E doctoral degree recipients entering postdocs; this rate fell from 31.5 percent of 1998 graduates to 29.5 percent of 2000 graduates (figure 3-24). Although many fields registered a small drop in the incidence of postdocs, the overall decline can mainly be attributed to a decrease in postdocs in the life sciences 1 year after degree from 56.4 percent in 1999 to 48.1 percent in 2001.

Reasons for Taking a Postdoc

In 2001, for all fields of degree, 11.5 percent of postdocs gave "other employment not available" as their primary reason for accepting a postdoc, compared with 32.1 percent of postdocs in 1999 (table 3-16 and NSB 2002). Most respondents gave reasons consistent with the defined training and apprenticeship functions of postdocs (e.g., 30 percent said that postdocs were generally expected for careers in their fields, 21 percent said they wanted to work with a particular person, 21 percent said they sought additional training in their fields, and 12 percent said they sought additional training outside their specialty). In 1999, a high proportion of postdocs in the biological sciences (38 percent) and physics (38 percent) had reported "other employment not available" as the primary reason for being in a postdoc, but in 2001, both fields had below average rates for this particular indicator of labor market distress.

Figure 3-24
Recent doctorate recipients in postdoc positions, by years since degree: 1999 and 2001



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 1999 and 2001.

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What Were 1999 Postdocs Doing in 2001?

Of individuals in postdocs in April 1999, 36.5 percent remained in a postdoc in April 2001. This represented a small reduction from the 38.0 percent of 1997 postdocs still in their positions in 1999 (NSB 2002). Only 12.3 percent had moved from a postdoc to a tenure-track position at a 4-year educational institution, down from 15.1 percent of 1997 postdocs in 1999; 20.2 percent had found other employment at an educational institution; and 31.0 percent had found some other form of employment (figure 3-25).

There is no available information on the career goals of individuals in postdoc positions. It is often assumed that a postdoc is valued most by academic departments at research universities. However, more postdocs in every field eventually accept employment with for-profit firms than obtain tenure-track positions, and many individuals accept tenure-track positions at schools that do not emphasize research.

Salaries for Recent S&E Ph.D. Recipients

In 2001, for all fields of degree, the median annual salary for recent S&E doctoral degree recipients reached $53,000, an increase of 8.2 percent from 1999. Across various S&E fields of degree, median annual salaries ranged from a low of $40,000 in the life sciences to a high of $75,000 in engineering (table 3-17). Among all doctoral degree recipients, individuals in the top 10 percent of salary distribution (90th

Table 3-16
Primary reason for taking current postdoc position, by degree field: 2001
(Percent)

Doctorate field	Additional training in field	Training outside field	Postdoc position generally expected in field	Association with particular person or place	Other employment not available	Other
All S&E fields	20.7	12.3	29.9	21.0	11.5	4.5
Biological sciences	21.0	12.3	34.3	18.7	9.4	4.2
Chemistry	15.5	16.9	26.9	18.2	19.0	3.6
Engineering	26.9	14.1	13.3	22.8	16.0	6.9
Geosciences	27.0	10.5	23.3	27.0	11.4	0.8
Physics	11.8	13.0	29.5	35.3	5.5	4.9
Psychology	27.2	11.6	35.5	15.9	7.9	2.9

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2001.

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Table 3-17
Median annual salary of recent doctorate recipients 1–3 years after receiving degree, by percentile: 2001
(Dollars)

	Percentile				
Doctorate field	10th	25th	50th	75th	90th
All S&E fields	30,000	38,000	53,000	65,000	90,000
Engineering	48,000	60,000	75,000	87,000	100,000
Life sciences	28,300	32,000	40,000	60,000	75,000
Mathematics/computer sciences	37,500	45,000	68,800	90,000	108,000
Physical sciences	30,000	39,000	56,000	75,900	87,000
Social sciences	30,000	39,000	47,000	60,000	80,500

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2001.

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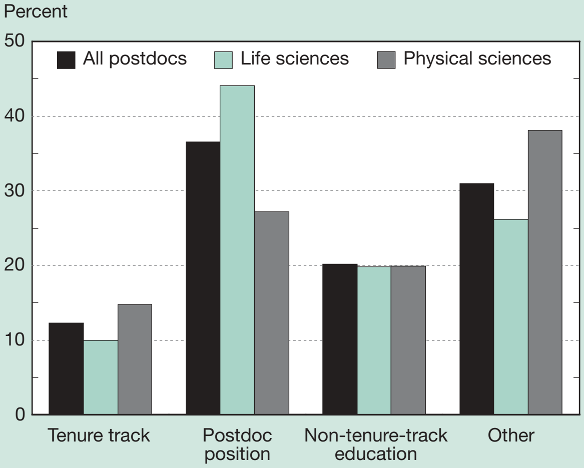
Figure 3-25
Status of 1999 S&E postdocs: 2001



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2001.

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percentile) earned a median annual salary of $90,000. The 90th percentile salaries varied by field, from a low of $80,500 for individuals with degrees in the social sciences to a high of $108,000 for recent doctoral degree recipients in mathematics and computer sciences. At the 10th percentile, representing the lowest pay for each field, salaries ranged from $28,300 for recent doctoral degree recipients in the life sciences to $48,000 for individuals receiving degrees in engineering.

Table 3-18 shows changes in median annual salaries for recent bachelor's, master's, and doctoral degree recipients (1–5 years since receipt of degree) for the period from 1997 to 1999. For all S&E fields, median salaries for recent doctoral degree recipients rose 4.7 percent from 1997 to 1999. For bachelor's and master's degree graduates, median salaries rose 0.0 and 2.5 percent, respectively. Several individual disciplines reflected larger increases for doctoral degree recipients; this included double-digit increases in economics (10.3 percent), physics (10.4 percent), computer sciences (12.0 percent), and mathematics (12.5 percent). A decline in median salaries occurred in biology (–3.7 percent).

Salary is measured here as a labor market outcome for all graduates, regardless of occupation or section of employment. Hence some of the changes may reflect different

Table 3-18
Change from 1997 to 1999 in median salary for S&E graduates 1–5 years after receiving degree
(Percent)

Degree field	Bachelor's	Master's	Doctoral
All S&E fields	0.0	2.5	4.7
Engineering	7.5	10.0	7.5
Chemical	11.9	5.2	3.1
Civil	5.7	4.2	9.1
Electrical	9.3	9.1	7.1
Mechanical	8.8	2.0	3.3
Life sciences	0.0	6.3	–2.8
Agriculture	0.0	11.3	10.1
Biological sciences	0.0	6.3	–3.7
Mathematics/computer sciences	13.5	7.7	9.7
Computer sciences	9.8	9.1	12.0
Mathematics	3.5	12.5	12.5
Physical sciences	0.0	9.9	8.3
Chemistry	3.7	14.3	2.9
Geoscience	–3.6	–7.7	5.0
Physics	0.0	11.1	10.4
Social sciences	3.8	6.1	7.1
Economics	15.2	0.0	10.3
Political science	7.1	8.1	12.5
Psychology	4.2	1.3	1.2
Sociology/anthropology	4.2	3.3	12.6

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1997 and 1999.

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proportions going into academia or to even lower paying postdoc positions.

Age and Retirement

The age distribution and retirement patterns of the S&E labor force greatly affect its size, its productivity, and opportunities for new S&E workers. For many decades, rapid increases in new entries into the workforce led to a relatively young pool of workers, with only a small percentage near traditional retirement age. Now, the general picture is rapidly changing as individuals who earned S&E degrees in the late 1960s and early 1970s move into the latter part of their careers.

Some controversy exists about the possible effects of age distribution on scientific productivity. Increasing average age may mean increased experience and greater productivity among scientific workers. However, others argue that it could reduce opportunities for younger scientists to work independently. In many fields, scientific folklore as well as actual evidence indicates that the most creative research comes from younger people (Stephan and Levin 1992).

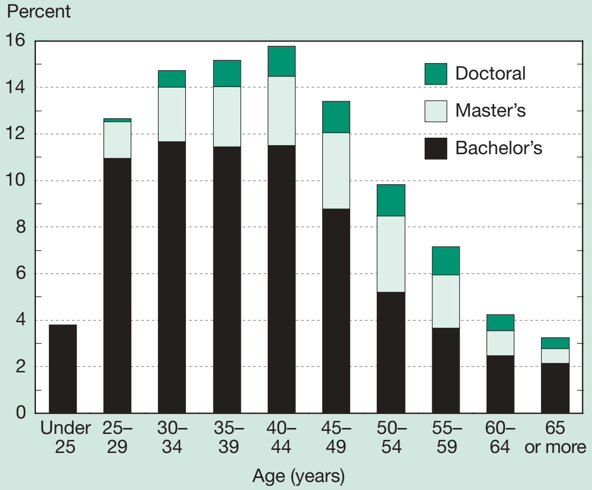
This section does not attempt to model and project future S&E labor market trends; however, some general conclusions can be made. Absent changes in degree production, retirement patterns, or immigration, the number of S&E-trained workers in the labor force will continue to grow for some time, but the growth rate may slow significantly as a dramatically greater proportion of the S&E labor force reaches traditional retirement age. As the growth rate slows, the average age of the S&E labor force will increase.

Implications for S&E Workforce

Net immigration, morbidity, mortality, and, most of all, historical S&E degree production patterns affect age distribution among scientists and engineers in the workforce. Appendix table 3-18 shows age distributions for S&E degree recipients in 1999, by degree level and broad field of degree. With the exception of new fields such as computer sciences (in which 56 percent of degree holders are younger than age 40), the greatest population density of individuals with S&E degrees occurs between the ages of 40 and 49. (Figure 3-26 shows the age distribution of the labor force with S&E degrees broken down by level of degree.) In general, the majority of individuals in the labor force with S&E degrees are in their most productive years (from their late 30s through their early 50s), with the largest group ages 40–44. More than half of workers with S&E degrees are age 40 or older, and the 40–44 age group is nearly four times as large as the 60–64 age group.

This general pattern also holds true for those individuals with S&E doctorate degrees. Ph.D. holders are somewhat older than individuals who have less advanced S&E degrees; this circumstance occurs because there are fewer doctorate holders in younger age categories, reflecting that time is needed to obtain this degree. The greatest population density of S&E Ph.D. holders occurs between the ages of 45 and 54. This can be most directly seen in figure 3-26, which

Figure 3-26
Age distribution of labor force with S&E highest degree, by degree level: 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999. See appendix table 3-18.

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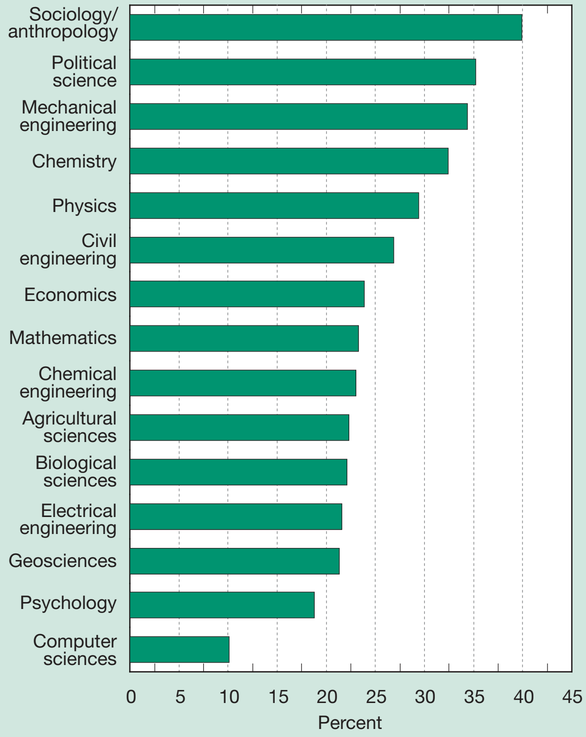
compares the age distribution of S&E degree holders in the labor force at each level of degree. Even if one takes into account the somewhat older retirement ages of doctorate holders, a much larger proportion of the doctorate holders are near traditional retirement ages than are individuals with either S&E bachelor's or master's degrees.

Across all degree levels and fields, 25.6 percent of the labor force with S&E degrees is older than age 50. The proportion ranges from 10.1 percent of individuals with their highest degree in computer sciences to 39.9 percent of individuals with their highest degree in sociology/anthropology (figure 3-27).

Taken as a whole, the age distribution of S&E-educated individuals suggests several likely important effects on the future S&E labor force:

- Barring large changes in degree production, retirement rates, or immigration, the number of trained scientists and engineers in the labor force will continue to increase, because the number of individuals currently receiving S&E degrees greatly exceeds the number of workers with S&E degrees nearing traditional retirement age.
- However, unless large increases in degree production occur, the average age of workers with S&E degrees will rise.
- Barring large reductions in retirement rates, the total number of retirements among workers with S&E degrees will dramatically increase over the next 20 years. This may prove particularly true for Ph.D. holders because of the steepness of their age profile. As retirements increase, the difference between the number of new degrees earned and the number of retirements will narrow (and ultimately disappear).

Figure 3-27
Employed S&E degree holders over age 50, by selected fields: 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999. See appendix table 3-19.

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Taken together, these factors suggest a slower-growing and older S&E labor force. Both trends would be accentuated if either new degree production were to drop or immigration to slow, both concerns raised by a recent report of the Committee on Education and Human Resources Task Force on National Workforce Policies for Science and Engineering of the National Science Board (NSB 2003).

S&E Workforce Retirement Patterns

The retirement behavior of individuals can differ in complex ways. Some individuals retire from one job and continue to work part time or even full time at another position, sometimes even for the same employer. Others leave the workforce without a retired designation from a formal pension plan. Table 3-19 summarizes three ways of looking at changes in workforce involvement for S&E degree holders: leaving full-time employment, leaving the workforce, and retiring from a particular job.

By age 62, 50 percent of both S&E bachelor's and master's degree recipients no longer work full time; however, S&E doctorate holders do not reach the 50 percent mark until age 66. Longevity also differs by degree level when measuring the number of individuals who leave the workforce entirely: half of S&E bachelor's and master's degree

Table 3-19
First age at which more than 50 percent of S&E degree holders are retired, by highest degree and employment status: 1999
(Years)

Highest degree	Not working full time	Not in labor force	Retired from any job
Bachelor's........	62	65	63
Master's..........	62	65	62
Doctoral..........	66	68	66

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999.

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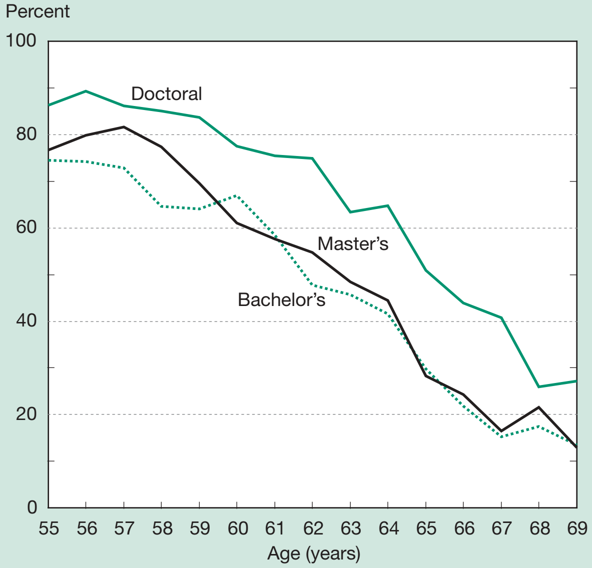
recipients had left the workforce entirely by age 65, but a similar proportion of Ph.D. holders did not do so until age 68. Formal retirement also occurs at somewhat higher ages for doctorate holders: more than 50 percent of bachelor's and master's degree recipients retired from employment by age 63, compared with age 66 for doctorate holders.

Figure 3-28 shows data on S&E degree holders leaving full-time employment at ages 55 through 69. For all degree levels, the portion of S&E degree holders who work full time declines fairly steadily by age, but after age 55, full-time employment for doctorate holders becomes significantly greater than for bachelor's and master's degree holders. At age 69, 27 percent of doctorate holders work full time compared with 13 percent of bachelor's or master's degree recipients.

Figure 3-28
Older S&E degree holders working full time, by degree level: 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999. See appendix table 3-20.

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The fact that a higher proportion of doctorate holders work in the academic sector or for the Federal Government may account for the slower retirement rate among doctorate holders. Table 3-20 shows rates at which doctorate holders left full-time employment, by sector of employment, between 1999 and 2001.[16] In 1999, within each age group, a smaller portion of doctorate holders employed at educational institutions (except at ages 66–70) or by the Federal Government (except at ages 71–73) left full-time employment compared with their counterparts employed in private noneducation sectors.

Although slower retirement rates (particularly in academia) for S&E doctorate holders are significant and of some policy interest, these slower rates do not mean that academic or other doctorate holders seldom retire. Indeed, figure 3-28 indicates retirement patterns similar to the ones for individuals holding bachelor's and master's degrees, with retirement simply delayed by 2 or 3 years. Even the 2-year transition rates for academia in table 3-20 show more than a third of individuals who were still working at ages 66 to 70 leaving full-time employment.

Although many S&E degree holders who formally retire from one job continue to work full or part time, this occurs most often among individuals younger than age 63 (table 3-21). The drop in workforce participation among the retired is more pronounced for part-time work; i.e., older retired S&E workers more often work full time than part time. Retired S&E doctorate holders follow this pattern, albeit with somewhat greater rates of postretirement employment than shown by bachelor's and master's degree recipients.

Global S&E Labor Force and the United States

"There is no national science just as there is no national multiplication table" *(Anton Chekhov, 1860–1904).*

Science is a global enterprise. The common laws of nature cross political boundaries, and the international movement of people and knowledge made science global long before "globalization" became a label for the increasing interconnections among the world's economies. The United States (and other countries as well) gains from new knowledge discovered abroad and from increases in foreign economic development.[17] U.S. industry also increasingly relies on R&D performed abroad. The nation's international economic competitiveness, however, depends upon the U.S. labor force's innovation and productivity.

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[16] As a practical matter, it would be difficult to calculate many of the measures of retirement used previously in this chapter by sector of employment. However, a 2-year transition rate can be calculated using the NSF/SRS SESTAT data file matched longitudinally at the individual level.

[17] A discussion of this is contained in Regets 2001.

Table 3-20
Employed 1999 S&E doctorate holders leaving full-time employment by 2001, by employment sector: 1999
(Percent)

Age in 1999 (years)	All sectors	Education	Private	Government
51–55	6.3	3.1	10.2	5.1
56–60	10.3	7.4	14.2	9.7
61–65	25.6	22.7	32.3	19.9
66–70	33.6	37.9	29.7	15.0
71–73	36.9	34.9	38.6	41.1

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999 and 2001.

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Table 3-21
S&E-degreed individuals who have retired but continue to work, by highest degree: 1999
(Percent)

	Bachelor's		Master's		Doctoral	
Age (years)	Part time	Full time	Part time	Full time	Part time	Full time
50–55	12.1	52.9	12.5	66.8	16.9	57.0
56–62	14.4	27.8	21.3	36.9	17.0	38.7
63–70	14.5	8.3	17.1	11.9	19.3	11.6
71–75	8.1	8.4	11.9	3.3	15.2	6.1

NOTE: Retired refers to individuals who said they had ever retired from any job.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999.

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Other chapters provide indirect indicators on the global labor force. Production of new scientists and engineers through university degree programs is reported in chapter 2. Indicators of R&D performed by the global S&E labor force are provided in chapter 4 (R&D expenditures and alliances), chapter 5 (publication output and international collaborations), and chapter 6 (patenting activity).

Section Overview

Although the number of researchers employed in the United States has continued to grow faster than the growth of the general workforce, this is still a third less than the growth rate for researchers across all Organisation for Economic Co-operation and Development (OECD) countries. Foreign-born scientists in the United States are more than a quarter, and possibly more than a third of the S&E doctorate labor force, and are even more prevalent in many physical science, engineering, and computer fields. Along with the increases in graduate education for domestic and foreign students elsewhere in the world (as discussed in chapter 2), there has been an increase in efforts by national governments and private industry to recruit the best talent from wherever it comes. As a result, the United States is becoming less dominant as a destination for migrating scientists and engineers.

Counts of the Global S&E Labor Force

Few direct measures of the global S&E labor force exist. Reports on the number of researchers in OECD member countries do constitute one source of data. From 1993 to 1997, the number of researchers[18] reported in OECD countries increased by 23.0 percent (a 5.3 percent average annual rate of increase) from approximately 2.46 million to 3.03 million (figure 3-29). During this same period, comparable U.S. estimates increased 11.8 percent (a 3.7 percent average annual rate of increase) from approximately 965,000 to 1.11 million. Although researchers in the United States, Japan, and the European Union made up 85.7 percent of the OECD total in 1997, the greatest growth in number of researchers came from other OECD countries, with a 120 percent increase from 196,000 to 433,000. (These numbers represent OECD staff estimates of total researchers in all member countries; the rapid growth of "other OECD" may represent in part improvements in reporting.)

Of course, non-OECD countries also have scientists and engineers. Figure 3-30 shows an estimate (from disparate data sources) of the global distribution of tertiary education graduates (roughly equivalent in U.S. terms to individuals who have earned at least technical school or associate's degrees, and also including all degrees up to doctorate) during

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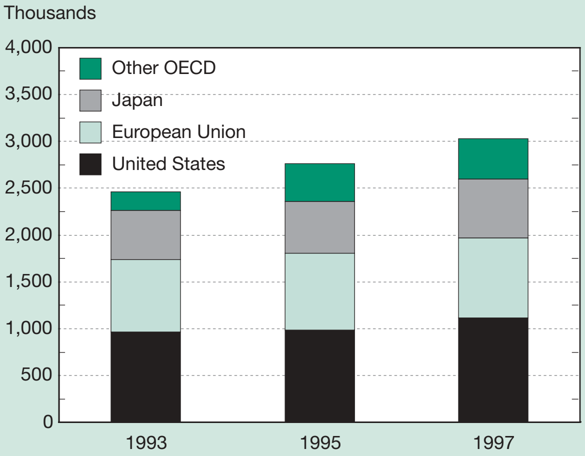
[18] The OECD defines researchers as "professionals engaged in conception and creation of new knowledge, products, processes, methods, and systems."

Figure 3-29
Researchers in OECD countries, by country/region: 1993, 1995, and 1997



OECD Organisation for Economic Co-operation and Development

SOURCE: OECD, *Main Science and Engineering Indicators,* various years.

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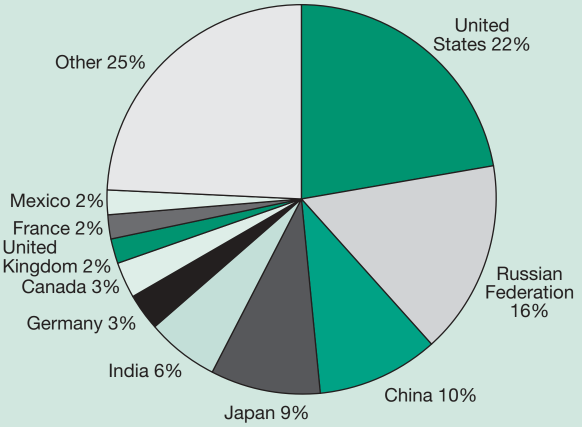
Figure 3-30
Global distribution of workers with tertiary education: 1990–98



NOTES: Estimates are based on various original data sources and reporting years and are not appropriate for direct comparison between countries but rather as an order-of-magnitude indicator of the global high-education workforce. No data are available from countries representing about 10 percent of global population. Tertiary education roughly corresponds to an associate's degree in the United States.

SOURCES: World Bank, *World Development Indicators,* annual series; National Bureau of Statistics of China: *1999 China Statistical Yearbook;* and Brazilian Institute for Geography and Statistics.

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the 1990s.[19] About one-fifth of the estimated 240 million tertiary graduates in the labor force were in the United States. However, of the 10 countries with the largest number of tertiary graduates, 3 do not belong to OECD: the Russian Federation, China, and India.

Migration to the United States

Migration of skilled S&E workers across borders is increasingly seen as a major determinant of the quality and flexibility of the labor force in most industrial countries. The knowledge of scientists and engineers can be transferred across national borders more easily than other skills. Additionally, cutting-edge research and technology inevitably create unique sets of skills and knowledge that can be transferred through the physical movement of people. The United States has benefited, and continues to benefit, from this international flow of knowledge and personnel. However, competition for skilled labor continues to increase. An NSB taskforce noted "[g]lobal competition for S&E talent is intensifying, such that the United States may not be able to rely on the international S&E labor market to fill unmet skill needs" (NSB 2003). (See sidebar, "High-Skill Migration to Japan")

In April 1999, SESTAT figures indicated that at least 27 percent of S&E doctorate holders in the United States were foreign born (table 3-22), along with 20 percent of those with S&E master's degrees and 10 percent of S&E bachelor's degree holders. Technical reasons make it difficult to estimate the extent of participation of foreign-born scientists and engineers in the U.S. S&E workforce in the 1990s.[20] Minimum estimates based on a sample drawn originally from the 1990 Census have turned out to be considerably low, reflecting the difficulty in measuring the dimensions of high-skilled entry into the U.S. during the 1990s.

An indication of the scope of the undercounting of foreign-born scientists and engineers comes from a comparison of SESTAT occupational data with approximately comparable data from the 2000 Census. Using the 5 percent Public Use Microdata Sample (PUMS), it is possible to compare the proportion of foreign-born individuals among

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[19] The primary source is World Bank data on size and percentage of the labor force with a tertiary education, supplemented with data from various national data agencies. However, these data come from different years for different countries and result from estimates taken from very different national data collection systems. Consequently, these data are not suitable for making direct comparisons between countries. In addition, data were not available from countries representing about 10 percent of the global population.

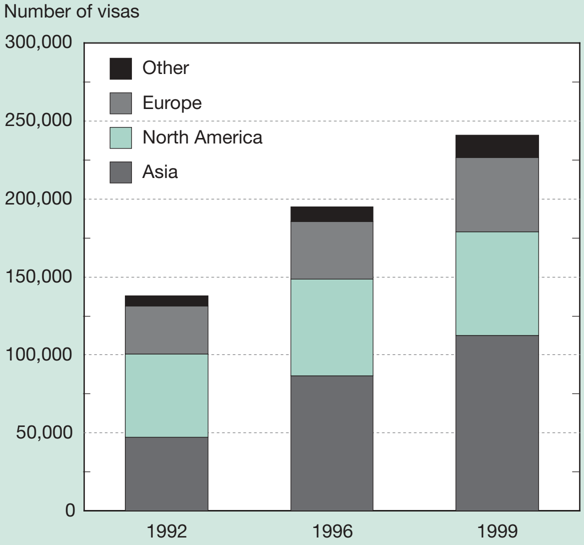
[20] Because the NSF's demographic data collection system cannot refresh its sample of individuals with S&E degrees from foreign institutions (as opposed to foreign-born individuals with a new U.S. degree, who are sampled) more than once per decade, counts of foreign-born scientists and engineers are likely to be underestimates. The 1999 estimate includes foreign-degreed scientists and engineers only to the extent that they were in the United States in April 1990. In 1993, 34.1 percent of foreign-born S&E doctorate recipients and 49.1 percent of foreign-born S&E bachelor's recipients had acquired their degrees from foreign schools (NSF/SRS 1999c).

High-Skill Migration to Japan

Recent political debate and legislative change in the United States, Germany, Canada, and many other developed countries have focused on visa programs for temporary high-skilled workers. A 1989 revision of Japanese immigration laws made it easier for high-skilled workers to enter Japan with temporary visas, which allow employment and residence for an indefinite period (even though the same visa classes also apply to work visits that may last for only a few months).

Scott Fuess of the University of Nebraska (Lincoln) and the Institute for the Study of Labor (Bonn) analyzed 12 Japanese temporary visa occupation categories associated with high-skilled workers. In 1999, 240,936 workers entered Japan in high-skilled visa categories, a 75 percent increase compared with 1992 (figure 3-31). For comparison purposes, this equals 40 percent of the number of Japanese university graduates entering the labor force each year and nearly doubles the number entering the United States in roughly similar categories (H-1b, L-1, TN, O-1, O-2) (Fuess 2001).

Figure 3-31
High-skilled worker visas in Japan, by country of origin: 1992, 1996, and 1999



SOURCE: S. Fuess, Jr., *Highly Skilled Workers and Japan: Is There International Mobility?* Workshop paper presented at Institute for the Study of Labor, Bonn, Germany, 2001).

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those with S&E occupations other than postsecondary teacher[21] (table 3-23). According to the 1999 SESTAT, 15.0 percent of college graduates in S&E occupations are foreign born, compared with the 22.4 percent recorded by the 2000 Census. A particularly noteworthy difference appears in the proportion of foreign-born individuals among those with doctorates; this proportion increases from 28.7 percent in SESTAT to 37.6 percent in the 2000 Census.

Among college-educated workers with occupations in the life sciences, physical sciences, and mathematical and computer sciences, estimates from the 2000 Census indicate that approximately one-fourth of individuals, across all degree levels, were foreign born (table 3-24). At the doctorate level, 51.3 percent of individuals in engineering occupations, and just under 45 percent in the life sciences, physical sciences, and mathematical and computer sciences, were foreign born. The lowest percentage of foreign-born individuals is found in social science occupations, where just over 10 percent of workers are foreign born (regardless of degree level).

The large increases shown by 2000 Census data may in part reflect recent arrivals in the United States, because 42.5 percent of all college-educated foreign-born individuals in S&E occupations reported arriving in the United States after 1990. Among foreign-born doctorate holders in S&E occupations, 62.4 percent reported arriving in the United States after 1990. The NSF/SRS estimates in table 3-23 include these post-1990 arrivals only if their degrees are from a U.S. institution.[22]

Origins of S&E Immigrants

Immigrant scientists and engineers come from a broad range of countries. Figure 3-32 shows countries contributing more than 30,000 individuals to the 1.5 million S&E degree holders in the United States, by S&E doctorate and by highest degree achieved in S&E. Although no one source country dominates, among individuals whose highest degree achieved is in S&E, 14 percent came from India, 10 percent came from China, and 5 percent each came from the following countries: Germany, the Philippines, the United Kingdom, Taiwan, and Canada. By region, 57 percent came from Asia (including the Western Asia sections of the Middle East), 24 percent came from Europe, 13 percent came from Central and South America, 6 percent came from Canada and Oceania, and 4 percent came from Africa.

Fiscal year 2001 data from the Bureau of Citizenship and Immigration Services (BCIS)[23] counts of permanent visas issued to immigrants in S&E show a large increase in permanent visas for S&E occupations to 33,917, dominated by growth in engineering and mathematical/computer sciences (figure 3-33). This reflects both a general increase in permanent visas issued due to efforts to eliminate backlogs (1,064,318 total permanent visas were issued in 2001), and the first opportunity for many workers on H-1b temporary work visas to adjust to permanent status. Adjustments from temporary work visas (which includes other cases besides H-1b) rose from 44,598 in FY 2000 to 85,227 in FY 2001. It

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[21] The 2000 Census occupation codes do not allow categorization of postsecondary teachers by field.

[22] It is also likely that noncitizens with U.S. degrees would not be part of NSF/SRS estimates if they reentered the United States during the 1990s after an extended period abroad.

[23] The Bureau of Citizenship and Immigration Services is one of the successor agencies to the Immigration and Naturalization Service, which was eliminated in early 2003.

Table 3-22
Foreign-born S&E-trained U.S. scientists and engineers, by field and level of highest degree: 1999
(Percent)

Field	All degree levels	Bachelor's	Master's	Doctoral
All S&E fields	12.2	9.9	19.9	27.0
Engineering	19.8	14.6	31.1	44.6
Chemical	20.2	14.9	34.9	40.8
Civil	21.2	16.1	35.5	51.5
Electrical	23.3	18.3	33.5	47.2
Mechanical	16.5	11.6	33.4	49.2
Other	17.0	11.3	24.2	40.9
Life sciences	11.7	8.8	13.7	26.1
Agriculture	7.9	5.4	14.9	22.7
Biological sciences	13.3	10.4	14.0	27.0
Mathematics/computer sciences	17.1	12.8	26.4	35.4
Computer sciences	21.1	15.2	34.3	46.4
Mathematics	12.5	10.2	15.4	31.1
Physical sciences	15.8	11.2	17.2	29.3
Chemistry	19.3	14.9	24.8	29.7
Geosciences	7.9	5.3	9.8	19.1
Physics/astronomy	18.2	9.8	18.9	32.5
Other	10.4	9.8	8.4	36.1
Social sciences	7.5	6.7	10.0	12.9
Economics	13.5	11.2	25.8	25.9
Political science	7.2	6.3	11.9	15.2
Psychology	6.2	6.1	6.4	7.6
Sociology/anthropology	6.1	5.3	12.4	12.7
Other	7.8	6.4	10.8	21.6

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999.

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Table 3-23
Comparison between NSF and Census estimates of foreign-born individuals in S&E occupations, by level of education: 1999 and 2000
(Percent)

Level of education	1999 NSF/SRS SESTAT	2000 Census 5-Percent PUMS
All college educated	15.0	22.4
Bachelor's	11.3	16.5
Master's	19.4	29.0
Professional degree	10.0	35.8
Doctorate	28.7	37.6

NSF/SRS National Science Foundation, Division of Science Resources Statistics
SESTAT Scientists and Engineers Statistical Data System
PUMS Public Use Microdata Sample

NOTE: Includes all S&E occupations other than postsecondary teachers because field of instruction was not included in occupation coding for the 2000 Census.

SOURCES: NSF/SRS, SESTAT, 1999; and U.S. Bureau of the Census, PUMS, 2000.

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is worth noting that FY 2001 ended on September 30, 2001, and thus was mostly unaffected by any changes in administrative practices or individual behaviors resulting from the events of September 11, 2001. (See sidebar, "Has September 11th Affected the U.S. Scientific Labor Force?")

Temporary Work Visas

In recent years, policy discussion has focused on the use of various forms of temporary work visas by foreign-born scientists. Many newspaper and magazine stories have been written about the H-1b visa program, which provides visas for up to 6 years for individuals to work in occupations requiring at least a bachelor's degree (or to work as fashion models). Although a common misperception exists that only information technology (IT) workers may use these visas, a wide variety of skilled workers actually use H-1b visas.

Exact occupational information on H-1b visas issued is not available. Some occupational data on H-1b admissions, which count individuals who re-enter the United States multiple times, does exist. This information can provide an approximate guide to the occupational distribution of individuals on H-1b visas. Individuals working in computer-related positions accounted for more than half (57.8 percent) of H-1b admissions, and architecture and engineering constituted another 12.2 percent. Another 9.0 percent labeled scientific and technical occupations and 8.7 percent in categories such as education and medicine also may include many individuals with S&E backgrounds (table 3-26).

An important change to the H-1b visa program took effect on October 1, 2003: the annual ceiling on admis-

Table 3-24
Foreign-born individuals in S&E occupations, by level of education and occupation group: 2000
(Estimated percent)

Level of education	All S&E occupations	Engineers	Life scientists	Mathematical/ computer scientists	Physical scientists	Social scientists
All college educated	22.4	20.8	25.6	24.7	26.8	11.3
Bachelor's	16.5	15.2	8.3	19.0	14.6	10.4
Master's	29.0	29.4	18.5	37.0	24.7	10.7
Professional degree	35.8	32.7	58.8	31.5	46.5	12.7
Doctorate	37.6	51.3	44.9	44.6	44.7	12.8

NOTE: Includes all S&E occupations other than postsecondary teachers because field of instruction was not included in occupation coding for the 2000 Census.

SOURCE: U.S. Bureau of the Census, Public Use Microdata Sample (PUMS) 2000 (5-percent sample).

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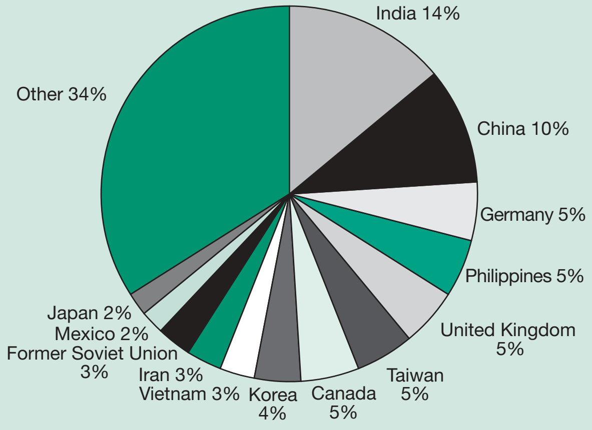
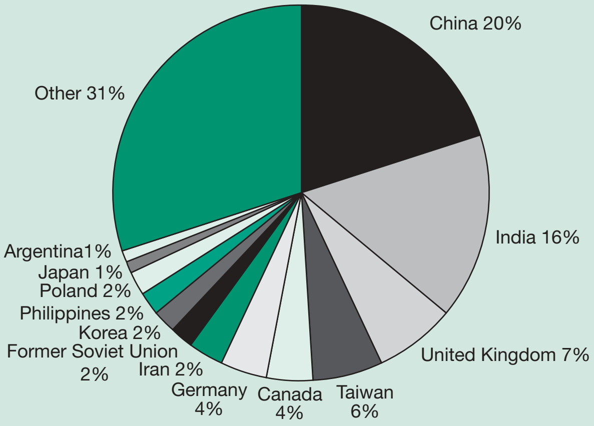
Figure 3-32
Foreign-born U.S. residents with S&E highest degree, by country of birth: 1999



S&E highest degrees



S&E doctorates

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999. See appendix tables 3-21 and 3-22.

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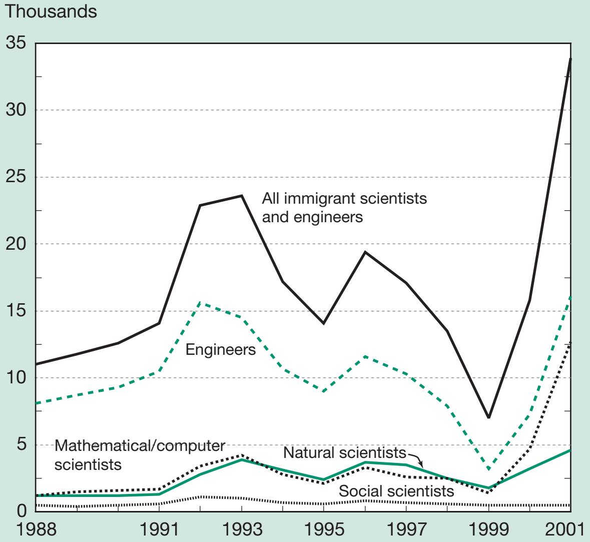
Figure 3-33
Permanent visas to individuals in S&E occupations, by occupation: 1988–2001



SOURCE: U.S. Department of Homeland Security, Bureau of Citizenship and Immigration Services, administrative data. See appendix table 3-23.

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sions fell from 195,000 to 65,000 due to the expiration of legislation that had allowed the additional visas. Although universities and academic research institutions are exempt from this ceiling, this change is likely to constrain the use of foreign scientists and engineers by private industry for any R&D located in the United States.

Scientists and engineers may also receive temporary work visas through intracompany transfer visas (L-1 visas), high-skilled worker visas under the North American Free Trade Agreement (TN-1 visas, a program currently primarily for Canadians, will grant full access for Mexican professionals by 2004), work visas for individuals with outstanding

Has September 11th Affected the U.S. Scientific Labor Force?

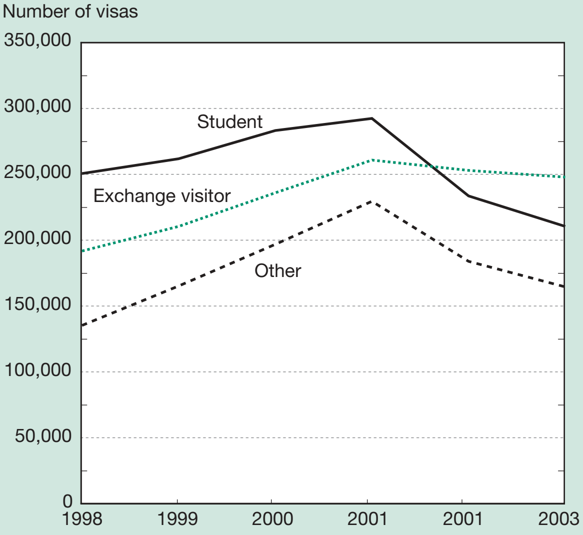
The ability and willingness of people to cross national borders crucially affects the science and technology enterprise in the United States. Foreign students help to fill graduate classrooms and laboratories. Visiting scientists facilitate the exchange of knowledge in ways that the telephone and the Internet cannot. Most importantly, foreign-born scientists constitute more than one-fourth of the science and engineering doctorate holders doing research in both academia and in industry. For this reason, a great deal of concerned speculation has focused on the effects of the tragic events of September 11, 2001, on the mobility of scientists to the United States. For most areas of concern, no data exists on even short-term effects. However, data is available on temporary visas issued by the State Department for fiscal year 2002, which began in October 2001, and for most of FY 2003 (table 3-25 and figure 3-34).

Between FY 2001 and FY 2002, the number of F-1 student visas issued dropped by 20.1 percent. A smaller drop (3.0 percent) occurred for exchange visitors (J-1), a category often used for visiting faculty and postdocs. For all categories of temporary work visas combined, the number dropped 19.8 percent. Part of the decline in temporary work visas may be explained by decreased demand due to economic conditions.

Although full FY2003 figures were not available at time of publication, further declines in high-skill related visas issued appear to have occurred. Counting just the period through September 14th of each fiscal year, student visas issued in 2003 were 27 percent below their 2001 peak. For the same 50-week period, the number of exchange visitor visas continued to decline slightly in 2003, to 4 percent below the 2001 level, and the number of other high-skill related visas issued declined by 26 percent.*

These declines occurred through two mechanisms—a decrease in the number of workers and students applying for visas and an increase in the proportion of visa applications rejected by the U.S. Department of State (table 3-25). Since FY 2001, the refusal rate for F-1 student visas has risen from 27.6 percent to 35.2 percent; at the same time, applications for F-1 visas fell by 18.5 percent. High-skilled related work visas followed a similar pattern, with applications down by 19.4 percent and the refusal rate increasing from 9.6 to 17.8 percent. However, exchange visitor visas followed a different pattern: applications rose from 2001 to 2003 but the total number of visas issued still declined due to a doubling of the refusal rate from 7.8 percent to 15.9 percent (table 3-25)

Figure 3-34
Student, exchange visitor, and other high-skill-related temporary visas issued: FY 1998–2003



NOTES: Student visa is F-1, exchange visitor visa is J-1, and other high-skill-related visas include L-1, H-1b, H-3, O-1, 0-2, and TN. FY 2003 data are through September 14 and thus exclude the last 2 weeks of the fiscal year.

SOURCE: U.S. Department of State, Immigrant Visa Control and Reporting Division. See appendix table 3-24.

Science & Engineering Indicators – 2004

Table 3-25
Visa applications by major high-skilled categories: FY 2001–2003

	Student (F-1)		Exchange visitor (J-1)		Other high-skill related visas	
Year	Applications	Percent refused	Applications	Percent refused	Applications	Percent refused
2001	399,988	27.6	279,524	7.8	248,421	9.6
2002	346,419	33.3	278,598	10.5	203,551	11.9
2003	325,844	35.2	295,624	15.9	200,233	17.8

NOTES: Data for each fiscal year are through September 14 and exclude last 2 weeks of reporting. Other high-skill related visas include L-1, H-1b, H-3, 0-1, O-2, and TN visas.

SOURCE: U.S. Department of State, Immigrant Visa Control and Reporting Division, administrative data.

Science & Engineering Indicators – 2004

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*An annual survey of U.S. schools by the Institute of International Education (2004) showed a slowdown in the growth of international students on U.S. campuses in academic year 2002/2003, but enrollment in S&E fields still grew by 2.7 percent. These numbers reflect changes in the existing stock of foreign students as well as new entrants in the first year after the decline in visa issuances. It is possible that the total number of foreign S&E students will grow for a short time even if there is a further decline in new entrants.

abilities (O-1 visas), and several smaller programs. In addition, there are temporary visas used by researchers who may also be students (F-1 and J-1 visas) or postdocs, and by visiting scientists (mostly J-1 visas but often H-1b visas or other categories). Counts of visas issued for each of these categories are shown in table 3-27. The annual quota of H-1b visas is controlled through issuance of visas to workers rather than through applications from companies.

Table 3-26
H-1b visa admissions, by occupation: FY 2001

Occupation	Number	Percent
All occupations	331,206	100.0
Computer related	191,397	57.8
Architecture, engineering, and surveying	40,388	12.2
Education	17,431	5.3
Medicine	11,334	3.4
Life sciences	6,492	2.0
Social sciences	6,145	1.9
Mathematical/physical sciences	5,772	1.7
Other professional/technical	5,662	1.7
Other (non-S&E related)	46,585	14.1

NOTE: Total admissions includes each entry to the United States and thus is much greater than the number of visas issued.

SOURCE: U.S. Department of Homeland Security, Bureau of Citizenship and Immigration Services, administrative data.

Science & Engineering Indicators – 2004

Stay Rates for U.S. Doctoral Degree Recipients With Temporary Visas

How many foreign students who receive S&E doctorates from U.S. schools remain in the United States? According to a report by Michael Finn (2003) of the Oak Ridge Institute for Science and Education, 56 percent of 1996 U.S. S&E doctoral degree recipients with temporary visas remained in the United States in 2001. The number of foreign students staying after obtaining their doctorates implies that approximately 3,500 foreign students remain from each annual cohort of new S&E doctorates in all fields. Stay rates differ by field of degree, ranging from only 26 percent in economics to 70 percent in computer and electrical engineering (table 3-28).

Table 3-27
Temporary visas issued in categories likely to include scientists and engineers: FY 2002

Visa type	Category	Number of visas
Work		
H-1b	Specialty occupations requiring bachelor's equivalent	118,351
L-1	Intracompany transfers	57,721
O-1	People of extraordinary ability	6,026
O-2	Workers assisting O-1	1,972
Student/exchange		
F-1	Students	234,322
J-1	Exchange visitors	253,841

SOURCE: U.S. Department of State, Immigrant Visa Control and Reporting Division, administrative data. See appendix table 3-24.

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Table 3-28
Temporary residents living in United States who received U.S. doctorates in 1996, by degree field: 1997–2001
(Percent)

Degree field	1997	1998	1999	2000	2001
All S&E fields	59	57	56	56	56
Agricultural sciences	40	38	37	38	38
Computer sciences	66	65	64	64	63
Computer/electrical engineering	73	72	70	70	70
Economics	27	27	27	27	26
Life sciences	65	63	61	63	63
Mathematics	59	59	57	57	57
Other engineering	62	59	59	58	58
Other social sciences	37	35	36	35	34
Physical sciences	66	65	63	63	64

SOURCE: M. Finn, Oak Ridge Institute for Science and Education, 2003.

Science & Engineering Indicators – 2004

Within each discipline, the stay rate remained mostly stable for the 1996 graduation cohort between 1997 and 2001. Quite possibly, however, some of this stability came from individuals in this cohort who re-entered the United States and thus replaced others in the same graduation cohort who left.

Conclusion

The U.S. S&E labor market continues to grow, both in absolute numbers and as a percentage of the total labor market. Although the most dramatic growth has occurred in the IT sector, other areas of S&E employment also have recorded strong growth over the past two decades.

In general, labor market conditions for individuals with S&E degrees improved during the 1990s. (These conditions have always been better than the conditions for college graduates as a whole.) However, engineering and computer science occupations have been unusually affected by the recent recession, causing the unemployment rate for individuals in S&E occupations to reach a 20-year high of 3.9 percent in 2002. Labor market conditions for new doctoral degree recipients have also been good, according to most conventional measures; for example, the vast majority of S&E doctorate holders are employed and doing work relevant to their training. However, these gains have come in the nonacademic sectors; that is, in nearly all fields, a smaller percentage of recent doctoral degree recipients obtained tenure-track positions.

The globalization of the S&E labor force continues to increase as the location of S&E employment becomes more internationally diverse and S&E workers become more internationally mobile. These trends reinforce each other as R&D spending and business investment crosses national borders in search of available talent, as talented people cross borders in search of interesting and lucrative work, and as employers recruit and move employees internationally. Although these trends appear most strongly in the high-profile international competition for IT workers, they affect every science and technology area.

The rate of growth of the S&E labor force may decline rapidly over the next decade due to the aging of individuals with S&E educations, as the number of individuals with S&E degrees reaching traditional retirement ages is expected to triple. If this slowdown does occur, the rapid growth in R&D employment and spending that the United States has experienced since World War II may not be sustainable.

The growth rate of the S&E labor force would also be significantly reduced if the United States becomes less successful in the increasing international competition for immigrant and temporary nonimmigrant scientists and engineers. Many countries are actively reducing barriers to high-skilled immigrants entering their labor markets at the same time that entry into the United States is becoming somewhat more difficult.

Slowing of the S&E labor force growth would be a fundamental change for the U.S. economy, possibly affecting both technological change and economic growth. Some researchers have raised concerns that other factors may even accentuate the trend (NSB 2003). Any sustained drop in S&E degree production would produce not only a slowing of labor force growth, but also a long-term decline in the S&E labor force.

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Chapter 4
U.S. and International Research and Development: Funds and Technology Linkages

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Highlights

National R&D Trends

- **Research and development expenditures continued to grow in the United States, reaching an estimated $276 billion in 2002.** But the rapid rate of growth of the late 1990s slowed considerably in 2001 and 2002.
- **Industry performed an estimated $194 billion of R&D in 2002, or 70 percent of the national total.** Industry was also the largest source of R&D funding, paying for 65 percent of all R&D. Nearly all (98 percent) of these funds flowed to industry; the remainder financed R&D at universities, colleges, and nonprofit organizations.
- **In the industrial sector in 2001, computer and electronic products manufacturing performed 24 percent ($47 billion) of all industrial R&D and 17 percent of the nation's total R&D.** The next largest industrial sector, transportation equipment, performed $26 billion in R&D in 2001. Nonmanufacturing industries associated with software and computer-related services performed between $24 and $25 billion of R&D in 2001.
- **Universities and colleges performed an estimated $36 billion of R&D in 2002, or 13 percent of the national total.** However, universities and colleges performed the majority (54 percent) of all basic research.
- **In 2000 California had the highest level of R&D expenditures among all states, $55 billion.** However, the ratio of R&D to gross state product was highest in Michigan at 5.8 percent compared with 4.1 percent in California.

Federal R&D Performance and Support

- **Federal R&D support, in absolute terms, expanded from $66 billion to an estimated $78 billion between 2000 and 2002.** This growth increased the Federal R&D support share of total U.S. R&D from 25 to 28 percent. In contrast, Federal laboratories and federally funded research and development centers performed only 12 percent of U.S. R&D in 2002.
- **In fiscal year 2003 the Department of Defense (DOD) is expected to obligate the most funds among Federal agencies for R&D support—$45 billion, or 46 percent of all Federal R&D obligations.** The Department of Health and Human Services (HHS) is expected to obligate the second largest amount in R&D support ($28 billion), followed by the National Aeronautics and Space Administration ($9 billion), the Department of Energy (DOE) ($8 billion), and the National Science Foundation ($3 billion).
- **The budget allocation for counterterrorism-related R&D increased dramatically between FY 2001 and FY 2003 from $0.6 to $2.9 billion.** Most of this budget now falls under the aegis of the National Institutes of Health and the newly formed Department of Homeland Security.
- **In 1999 (the latest year for which these data are available), 10,000 companies claimed $5.3 billion in R&D tax credits, about the same level as in 1998.** In 1999, 267 companies claimed $540 million for basic research, about 10 percent of the total research and experimentation credit.

Technology Linkages: Contract R&D, and Federal Technology Transfer

- **In 2001, more than 1,300 manufacturing companies (or 8 percent of all manufacturing R&D-performing companies) reported contract R&D expenditures of $4 billion in the United States.** Contract R&D expenditures as a proportion of in-house company-funded R&D is particularly notable in pharmaceuticals and R&D services.
- **Federal technology transfer activities continued to rise.** In FY 2001, 10 Federal agencies reported more than 3,900 invention disclosures and filed nearly 2,200 patent applications. Patent applications increased to a peak of 2,172 in FY 2001, up 4.3 percent from FY 2000. Patents issued to these Federal agencies reached 1,608 in FY 2001, up 15.6 percent from FY 2000.
- **The same 10 Federal agencies executed 926 new cooperative R&D agreements (CRADAs) with industrial and university partners in FY 2001, up 5.9 percent from FY 2000, bringing the number of active CRADA agreements to 3,603.** DOD, DOE, and HHS accounted for more than 80 percent of active CRADAs in FY 2001.
- **The Small Business Innovation Research Program (SBIR), designed to stimulate technical innovation by small firms and their participation in Federal R&D funding, awarded $1.29 billion in R&D funding to 4,748 projects in FY 2001.** DOD led the 10 participating agencies in obligated SBIR funding at $576 million (45 percent of all SBIR funding), followed by HHS at $412 million (32 percent).

Technology Linkages: R&D Collaboration

- **From 1985 to 2001 a total of 861 technology alliances were registered in filings required by the National Cooperative Research and Production Act.** About half of the technology alliances during the period 1985–2001 involved activities classified in three industrial areas: electronic and electrical equipment, communication services, and transportation equipment. Fifteen percent (125 of 861) of these alliances involved a U.S. university, whereas about 12 percent (99 of 861) included a Federal laboratory.
- **A separate database covering international alliances shows that in 2001 there were 602 new international technology alliances in six major sectors, notably information technology and biotechnology/pharmaceuticals, up from 483 in 2000, a 25 percent increase.** This is the first increase since a 19.5 percent increase in 1995 to its all-

time high of 674 technology alliances. From 1991 to 2001, there were 5,892 new technology alliances. About 80 percent (4,646 of 5,892) of the 1991–2001 technology alliances worldwide involved at least one U.S.-owned company.

International R&D Trends and Comparisons

- **The United States accounts for approximately 44 percent of total R&D expenditures in all Organisation for Economic Co-operation and Development (OECD) countries combined.** R&D investments in the United States are 2.7 times greater than R&D investments made by Japan, the second largest performer. In 2000 the United States spent more on R&D activities than all other "group of seven" (G-7) countries (Canada, France, Germany, Italy, Japan, and the United Kingdom) combined.
- **A noteworthy trend among G-7 and other OECD countries has been the relative decline in government R&D funding over the past 2 decades.** In 2000, less than 30 percent of all OECD R&D funds were derived from government sources, down considerably from the 44 percent share reported in 1981. In aggregate terms, this change reflects a decline in industrial reliance on government funds for R&D performance.
- **As a result of a worldwide slowing in R&D spending during the early 1990s, the latest ratio of R&D spending to gross domestic product (R&D/GDP) for most G-7 countries is no higher now than it was a decade ago.** The United States, devoting 2.7 percent of its GDP to R&D, ranked fifth among OECD countries during the 1996–2001 period. Sweden led OECD countries at 3.8 percent of its GDP devoted to R&D, followed by Finland (3.4 percent), Japan (3.0 percent), and Iceland (2.9 percent).
- **As an indication of an overall pattern of increased university-firm interactions, the proportion of academic R&D funding from industry sources (for G-7 countries combined) climbed from 2.6 percent of the academic R&D total in 1981 to 5.2 percent in 1990 and to 6.0 percent in 1999.**
- **Among nondefense objectives, government R&D spending shares changed during the 1981–99 period: government R&D shares increased most for health and the environment and for various nondirected R&D (including many basic research) activities.** Conversely, the relative share of government R&D support provided for economic development programs (which include the promotion of agriculture, fisheries and forestry, industry, infrastructure, and energy) declined considerably.

R&D Investments by Multinational Corporations

- **Foreign-owned firms conducting R&D in the United States accounted for $26.1 billion (13 percent) of the $199.5 billion in total industrial R&D expenditures in the United States in 2000.** This share fluctuated between 11 and 13 percent during the period 1994–2000.
- **In 2000 about two-thirds of foreign-owned R&D in the United States was performed in three industries: chemicals (27 percent), computer and electronic products (24 percent), and transportation equipment (12 percent).** Seven countries invested $1 billion or more in R&D in the United States in 2000: Canada, France, Germany, Japan, the Netherlands, Switzerland, and the United Kingdom, accounting for about 90 percent of all R&D expenditures by foreign-owned firms in the United States.
- **Parent companies of U.S. multinational corporations accounted for two-thirds of the R&D spending by all industrial R&D performers in the United States in 2000.** These parent companies had R&D expenditures of $131.6 billion in the United States in 2000, whereas their majority-owned foreign affiliates had R&D expenditures of $19.8 billion, for a total of $151.3 billion in global R&D expenditures.
- **Two-thirds of the R&D performed overseas in 2000 by U.S.-owned subsidiaries ($13.2 of $19.8 billion) took place in six countries: Canada, France, Germany, Japan, Sweden, and the United Kingdom.** Three-fourths of this overseas R&D activity was performed in three manufacturing sectors: transportation equipment ($5.7 billion, or 29 percent), computer and electronic products ($4.9 billion, or 25 percent) and chemicals ($4.3 billion, or 22 percent). These are the same three industries that accounted for most foreign-owned R&D in the United States, implying a high degree of R&D internationalization in these industries.
- **Certain emerging markets played an increasing role in U.S.-owned overseas R&D.** In 2000, U.S. subsidiaries had R&D expenditures of $500 million or more in China, Ireland, Israel, and Singapore, increasing significantly their rank as hosts of R&D activities compared with that in 1994. U.S. computer and electronic products subsidiaries in Ireland, Israel, Singapore, South Korea, and Taiwan spent a total of $1.2 billion in R&D activities in 2000, or 25 percent of $4.9 billion in U.S.-owned overseas R&D in this industry.

Introduction

Chapter Overview

Research and development is widely recognized as being key to economic growth and social welfare, often resulting in benefits unimagined at the time it is initiated. Although R&D expenditures never have exceeded 3 percent of the U.S. gross domestic product (GDP) and the returns on investment in R&D have been difficult to measure, academic and government communities continue to study R&D expenditures as an indicator of technological change in and the innovative capacity of the nation.

The results of R&D decisionmaking—including the resources that various organizations devote to R&D and to what ends they devote them—affect both the economy and national well-being. For this reason, the United States and many other nations collect extensive R&D expenditure data, which are disseminated worldwide for study by analysts in a variety of fields.

In addition to indicating the direction and rate of technological change, R&D expenditure data also measure the level of economic purchasing power devoted to R&D projects compared with other economic activities. Industrial (private sector) funding of R&D, for example, may be considered an indicator of how important R&D is to companies because companies could easily devote those same funds to other business activities such as advertising. Similarly, government support for R&D reflects governmental and societal commitment to scientific and technological advancement, an objective that must compete for dollars against other functions supported by discretionary government spending. The same basic idea is true for the other sectors that fund R&D: universities, colleges, and other nonprofit organizations.

Although total R&D expenditures reveal the perceived economic importance of R&D relative to all other economic activities, the composition of R&D expenditures is a policy variable of equal importance (Tassey 1999). Over the R&D life cycle, different classes of R&D funders and performers rise in importance, then give way to others. The success or failure of technology-intensive industries relative to foreign competitors often hinges on the availability and effectiveness of these differing participants. R&D flows between the sectors represented by these participants indicate a nation’s capacity to leverage its science and technology (S&T) resources effectively.

In addition to R&D expenditures performed within a particular sector, this chapter presents data on outsourced and collaborative R&D activities across R&D-performing sectors and on Federal technology transfer. Technology sources outside a company or industry, including university research, have played a key role in innovation and competitiveness from the beginnings of corporate R&D in the United States (Mowery 1983; and Rosenberg and Nelson 1994). In recent decades, however, the increased relevance of scientific research to industrial technology, coupled with the demands from a global competitive environment, has increased the importance of collaborative activities for innovation and long-term competitiveness (Vonortas 1997).

Chapter Organization

This chapter is organized into five major sections that examine trends in R&D expenditures and collaborative technology activities. The first and second sections describe R&D performed in the United States. The first contains information on economic measures of R&D in the United States and trends in total R&D performance and funding; areas addressed include industrial R&D, R&D performance by state, and R&D performance and funding by character of work. The second focuses on the role of the Federal Government in the R&D enterprise, giving particular attention to direct Federal R&D support by national objective, Federal agency, and field of science as well as indirect fiscal measures to stimulate R&D growth.

The third section summarizes available information on external technology sourcing and collaborative R&D activities across R&D-performing sectors including industrial contract R&D expenditures, Federal technology transfer, and domestic and international technology alliances.

The fourth section compares R&D trends across nations. It contains sections on total and nondefense R&D spending; ratios of R&D to GDP in various nations; international R&D funding by performer and source (including information on industrial subsectors and academic science and engineering fields); the allocation of R&D efforts among basic research, applied research, and development components; and international comparisons of government R&D priorities and tax policies.

The fifth section discusses available R&D data for foreign-owned companies in the United States, parent companies of U.S. multinational corporations (MNCs), and U.S.-owned R&D overseas in terms of investing or host countries, their industrial focus, and implications for the ownership structure of U.S. R&D activity.

National R&D Trends

In the mid- to late 1990s, R&D performance in the United States surged.[1] In real terms (constant or inflation-adjusted dollars), total R&D performance grew 40.5 percent between 1994 and 2000 at an average annual real growth rate of 5.8 percent over the period (figure 4-1). National Science Foundation (NSF) data indicate that this growth rate was not sustained in the following 2 years, slowing to an estimated 1 percent between 2000 and 2001 and just keeping pace with inflation between 2001 and 2002. Total 2002 R&D performance in the United States is estimated to be $276.2 billion, up from an estimated $273.6 billion in 2001 and $264.7 billion in 2000.[2] (See sidebar, “Definitions of R&D.”)

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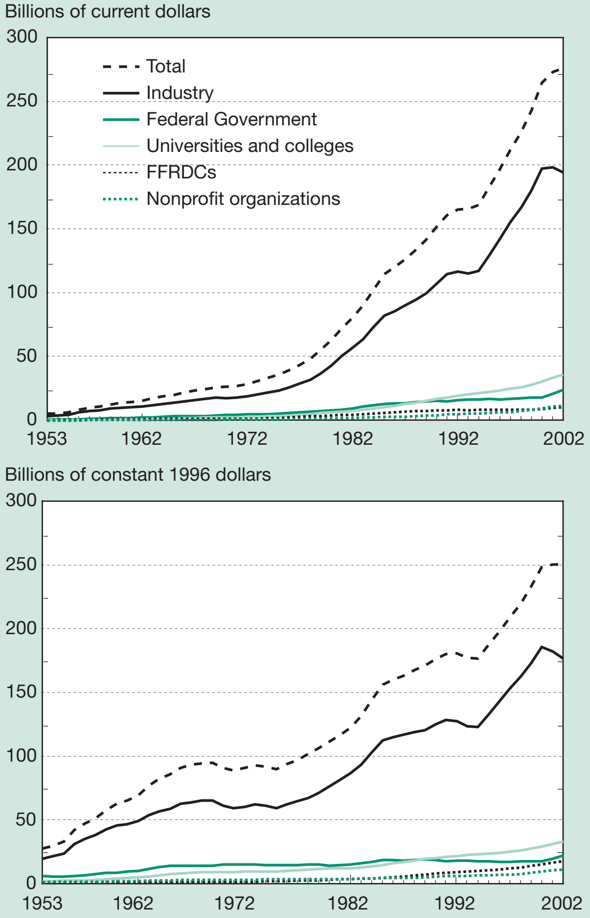
[1] Expenditures for research and development performance are used as a proxy for actual R&D performance. In this chapter, the phrases *R&D performance* and *expenditures for R&D performance* are interchangeable.

[2] At the time this report was written, estimated data for 2002 were the latest figures available for R&D expenditures.

Figure 4-1
National R&D performance, by performing sector: 1953–2002



FFRDC federally funded research and development center

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* annual series. See appendix tables 4-3 and 4-4.

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In comparison, GDP, the main measure of the nation's total economic activity, grew in real terms by 3.8 percent per year between 1994 and 2000. R&D performance as a proportion of GDP rose from 2.40 percent in 1994 to 2.69 percent in 2000 as growth in R&D outpaced the growth of the overall economy. The slowdown in R&D investment in 2001 and 2002 coincided with an overall economic slowdown in the United States, resulting in R&D to GDP ratios of 2.71 percent in 2001 and 2.64 percent in 2002.[3]

Organizations that perform R&D often receive outside funding; conversely, organizations that fund R&D often do not perform all the R&D themselves. Therefore, it is useful to analyze R&D expenditure data in terms of who performed the R&D and who funded it.

Definitions of R&D

The National Science Foundation (NSF) uses the following definitions in its research and development surveys. They have been in place for several decades and generally are consistent with international definitions.

R&D. According to international guidelines for conducting R&D surveys, R&D, also called research and experimental development, comprises creative work "undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" (OECD 2002f, p. 30).

Basic research. The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind. In industry, basic research is defined as research that advances scientific knowledge but does not have specific immediate commercial objectives, although it may be performed in fields of present or potential commercial interest.

Applied research. The objective of applied research is to gain the knowledge or understanding to meet a specific, recognized need. In industry, applied research includes investigations to discover new scientific knowledge that has specific commercial objectives with respect to products, processes, or services.

Development. Development is the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.

R&D plant. R&D plant includes the acquisition of, construction of, major repairs to, or alterations in structures, works, equipment, facilities, or land for use in R&D activities.

Budget authority. Budget authority is the authority provided by Federal law to incur financial obligations that will result in outlays.

Obligations. Federal obligations represent the dollar amounts for orders placed, contracts awarded, services received, and similar transactions during a given period, regardless of when funds were appropriated or payment was required.

Outlays. Federal outlays represent the dollar amounts for checks issued and cash payments made during a given period, regardless of when funds were appropriated or obligated.

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[3] The estimated U.S. gross domestic product (GDP) for 2000, 2001, and 2002 in constant 1996 dollars is $9,191 billion, $9,215 billion, and $9,440 billion, respectively. See appendix table 4-1 for a full time series.

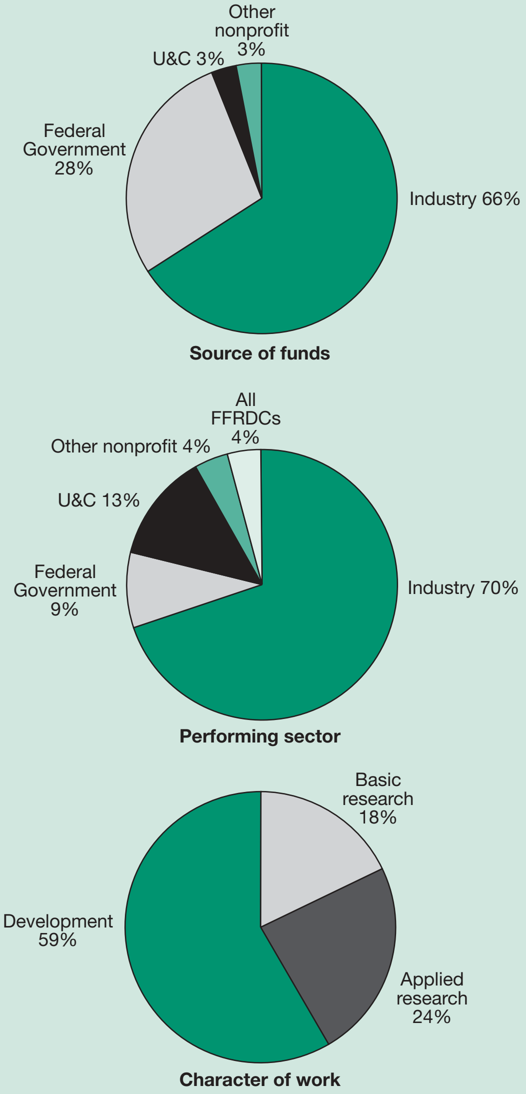
Industry performs most of the nation's R&D and accounted for 70.4 percent of total R&D performance in 2002.[4] Universities and colleges, excluding academically administered federally funded research and development centers (FFRDCs), accounted for 13.0 percent of national R&D performance in 2002, followed by the Federal Government (8.6 percent) and nonprofit institutions (4.2 percent).[5] All FFRDCs combined performed 3.7 percent of U.S. total R&D in 2002 (figures 4-1 and 4-2; table 4-1).

Private industry is also the largest source of R&D funding in the United States and provided 65.5 percent ($180.8 billion) of total R&D funding in 2002. Most of these funds (98.1 percent) flowed to industrial performers of R&D. The Federal Government provided the second largest share of R&D funding, 28.3 percent ($78.2 billion), with only 43.6 percent of these funds financing Federal labs and FFRDCs. The other sectors of the economy (i.e., state governments, universities and colleges, and nonprofit institutions) contributed the remaining 6.2 percent ($17.2 billion) (table 4-1).

Trends in R&D Performance

U.S. R&D has experienced largely uninterrupted growth over the past 50 years (figure 4-1). U.S. R&D performance grew each year between 1953 and 2002, even in the early 1990s when both Federal and industrial R&D funding slowed significantly[6] (figure 4-3). In the mid-1990s substantial increases in industrial R&D, most notably in the computer and other information technology (IT) sectors and in small R&D-performing firms, ended a brief slowdown in national R&D growth.[7] Between 1994 and 2000, an 8.9 percent real annual growth rate in industrial support for R&D overshadowed a slight decline (–0.3 percent per year) in Federal R&D support, resulting in overall real annual growth of 5.8 percent in U.S. R&D.

Figure 4-2
Shares of national R&D expenditures, by source of funds, performing sector, and character of work: 2002



FFRDC federally funded research and development center

NOTES: Figures are rounded to nearest whole number. National R&D expenditures were an estimated $276 billion in 2002.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources*, annual series. See appendix tables 4-3, 4-5, 4-7, 4-11, and 4-15.

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More recently, the growth of R&D investment in the United States has slowed. Preliminary data indicate that although total R&D expenditures continued to rise through 2002, industrial R&D, which fueled the growth over the prior period, failed to keep pace with inflation and experienced its first decline in real terms after 1994. This has occurred only six times in the past 49 years. The business activities of many R&D-performing firms were curtailed following the stock market decline and subsequent economic slowdown of 2001 and 2002. The same sectors that saw impressive

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[4] Unless otherwise noted, whenever a sector is mentioned in this chapter, federally funded research and development centers (FFRDCs) are excluded. FFRDCs are R&D-performing organizations that are exclusively or substantially financed by the Federal Government either to meet a particular R&D objective or, in some instances, to provide major facilities at universities for research and associated training purposes. Each FFRDC is administered either by an industrial firm, a university, or a nonprofit institution. In some of the statistics provided in this chapter, FFRDCs are included as part of the sector that administers them. In particular, statistics on the industrial sector often include industry-administered FFRDCs because some of the statistics from the National Science Foundation (NSF) Survey of Industrial Research and Development before 2001 cannot be separated from the FFRDC component.

[5] Recent methodological improvements have resulted in revisions from the amounts previously reported for total academic R&D expenditures. For more information, see M. Machen and B. Shackelford, *Academic R&D Spending Maintains Growth From All Major Sources in FY 2001,* NSF InfoBrief (forthcoming).

[6] These findings are based on performer-reported R&D levels. In recent years, increasing differences have been detected in data on federally financed R&D as reported by Federal funding agencies and by performers of the work (most notably, industrial firms and universities). This divergence in R&D totals is discussed subsequently in this chapter. (See sidebar, "Tracking R&D: Gap Between Performer- and Source-Reported Expenditures.")

[7] For most manufacturing industries, the U.S. Small Business Administration defines *small firm* as one with 500 or fewer employees. The share of company-financed R&D performed by these firms grew from 10 percent in 1990 to a peak of 20 percent in 1999.

Table 4-1

U.S. R&D expenditures, by character of work, performing sector, and source of funds: 2002

Performing sector	Total	Industry	Federal Government	U&C	Other nonprofit institutions	Percent distribution of total expenditures
	Millions of dollars					
R&D	276,185	180,769	78,185	7,455	7,304	100.0
Industry	194,430	177,345	17,085	—	—	70.4
Industry-administered FFRDCs	2,235	—	2,235	—	—	0.8
Federal Government	23,788	—	23,788	—	—	8.6
U&C	36,019	2,341	21,066	7,455	2,685	13.0
U&C-administered FFRDCs	6,060	—	6,060	—	—	2.2
Other nonprofit institutions	11,620	1,083	5,918	—	4,619	4.2
Nonprofit-administered FFRDCs	2,034	—	2,034	—	—	0.7
Percent distribution by source	100.0	65.5	28.3	2.7	2.6	—
Basic research	49,566	9,186	29,218	6,767	4,395	100.0
Industry	7,751	6,989	762	—	—	15.6
Industry-administered FFRDCs	611	—	611	—	—	1.2
Federal Government	4,617	—	4,617	—	—	9.3
U&C	26,677	1,596	16,484	6,767	1,830	53.8
U&C-administered FFRDCs	2,962	—	2,962	—	—	6.0
Other nonprofit institutions	6,020	601	2,854	—	2,565	12.1
Nonprofit-administered FFRDCs	928	—	928	—	—	1.9
Percent distribution by source	100.0	18.5	58.9	13.7	8.9	—
Applied research	64,803	39,833	20,507	2,591	1,872	100.0
Industry	42,590	38,947	3,643	—	—	65.7
Industry-administered FFRDCs	304	—	304	—	—	0.5
Federal Government	8,083	—	8,083	—	—	12.5
U&C	8,008	611	4,105	2,591	701	12.4
U&C-administered FFRDCs	1,645	—	1,645	—	—	2.5
Other nonprofit institutions	3,902	275	2,456	—	1171	6.0
Nonprofit-administered FFRDCs	271	—	271	—	—	0.4
Percent distribution by source	100.0	61.5	31.6	4.0	2.9	—
Development	161,817	131,750	28,460	569	1038	100.0
Industry	144,089	131,409	12,680	—	—	89.0
Industry-administered FFRDCs	1,320	—	1,320	—	—	0.8
Federal Government	11,088	—	11,088	—	—	6.9
U&C	1,334	134	477	569	154	0.8
U&C-administered FFRDCs	1,452	—	1,452	—	—	0.9
Other nonprofit institutions	1,699	207	608	—	884	1.0
Nonprofit-administered FFRDCs	835	—	835	—	—	0.5
Percent distribution by source	100.0	81.4	17.6	0.4	0.6	—

FFRDC federally funded research and development center
U&C universities and colleges

NOTES: State and local government support to industry is included in industry support for industry performance. State and local government support to U&C ($2,472 million in total R&D) is included in U&C support for U&C performance.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* annual series. See appendix tables 4-3, 4-7, 4-11, and 4-15.

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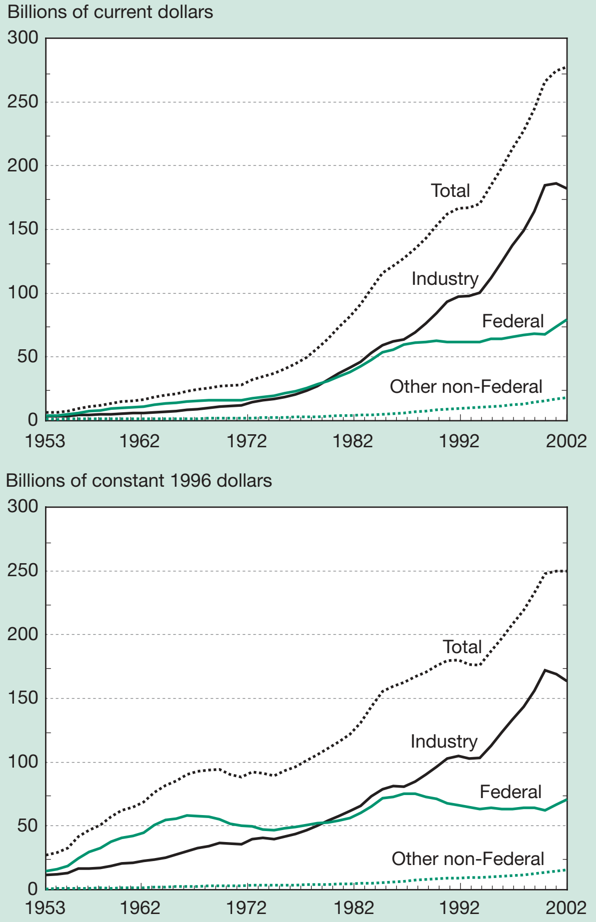
Figure 4-3
National R&D funding, by source of funds: 1953–2002



SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources*, annual series. See appendix tables 4-3 and 4-4.

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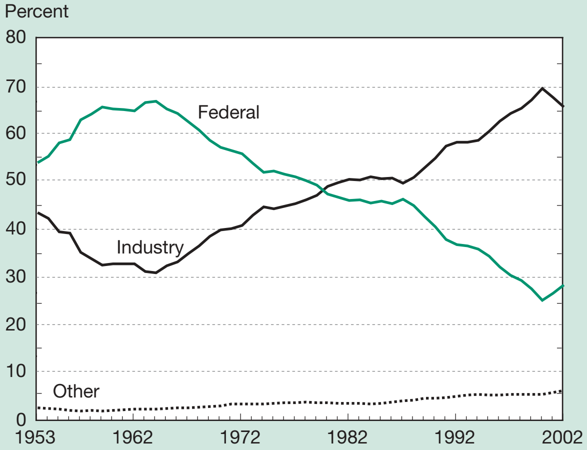
increases in the late 1990s experienced declines in sales, share prices, and R&D investment at the beginning of the 21st century.

Trends in Federal R&D Funding

Increases in Federal R&D investment, particularly in the areas of defense, health, and counterterrorism, helped to offset the slowdown in industrial R&D in 2001 and 2002. These increases also reversed a decades-long trend in the shrinking share of Federal R&D funding as a percentage of the nation's total R&D (figure 4-4).

The Federal Government was once the main source of the nation's R&D funds, funding as much as 66.7 percent of all U.S. R&D in 1964. The Federal share first fell below 50 percent in 1979, and after 1987 it fell steadily, dropping from 46.3 percent in that year to 25.1 percent in 2000 (the lowest it has ever been since the start of the time series in 1953). This sharp decline in the Federal Government share, however, should not be misinterpreted as a drastic decline in the actual amount of R&D funded (figure 4-3). Adjusting for inflation, Federal support decreased 18 percent from 1987 to 2000, although in nominal terms, Federal support grew from $58.5 billion to $66.4 billion during that period. Growth in industrial funding generally outpaced growth in Federal support, leading to the decline in Federal support as a proportion of the total. The slowdown of industry's investment in R&D, as well as increases in Federal R&D funding in recent years, reversed this trend. Thus in 2002, the Federal share of R&D funding is estimated to have grown to 28.3 percent.

Figure 4-4
National R&D expenditures, by source of funds: 1953–2002



SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* annual series. See appendix table 4-5.

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Trends in Non-Federal R&D Funding

R&D financing from non-Federal sources grew by 7.6 percent per year after inflation between 1980 and 1985, concurrent with gains in Federal R&D spending. This growth rate slowed to 3.3 percent between 1985 and 1994 but rose to 8.6 percent during the 1994–2000 period. More recently, between 2000 and 2002, non-Federal sources of R&D funding declined by 1.8 percent per year in real terms.

As previously discussed, most non-Federal R&D support is provided by industry. Of the 2002 non-Federal support total ($198 billion), 91.4 percent ($181 billion) was company funded. Industry's share of national R&D funding first surpassed the Federal Government's in 1980, and it has remained higher ever since. From 1980 to 1985, industrial support for R&D, in real dollars, grew at an average annual rate of 7.7 percent. This growth was maintained through both the mild 1980 recession and the more severe 1982 recession (figure 4-3). Key factors behind increases in industrial R&D included a growing concern with international competition, especially in high-technology industries; the increasing technological sophistication of products, processes, and services; and general growth in such defense-related industries as electronics, aircraft, and missiles. Between 1985 and 1994, growth in R&D funding from industry was slower, averaging only 3.1 percent per year in real terms, but from 1994 to 2000 industrial R&D support grew in real terms by 8.9 percent per year. This rapid growth rate came to a halt following the downturn in both the market valuation and economic demand for technology in the first years of the 21st century. Between 2000 and 2002 industrial R&D support declined by 2.5 percent per year in real terms.

Although industrial firms provide only a small portion of the R&D funding at U.S. universities and colleges (6.5 percent in 2002), their funding of academic research has grown faster than any other sector over the past 2 decades. Between 1980 and 2000, industry's funding of academic R&D grew at an average annual rate of 7.7 percent after adjusting for inflation, outpacing total academic R&D, which grew at an average annual rate of 4.8 percent over the same period. Growth in industry's funding of academic R&D has since slowed to an average annual rate of 1.9 percent between 2000 and 2002, indicating that this source of funding is not immune to economic forces, although apparently more so than industry's R&D funding of industry itself.

R&D funding from other non-Federal sectors, namely, academic and other nonprofit institutions and state and local governments, has been more consistent over time, growing at an average annual rate of 6.3 percent between 1980 and 2002 after adjusting for inflation. Most of these funds went to research performed within the academic sector.

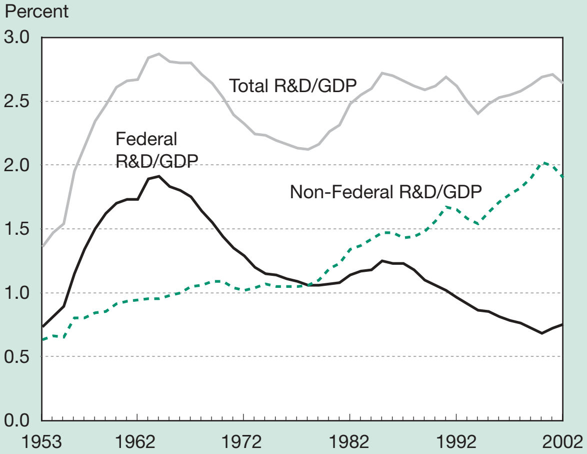
U.S. R&D/GDP Ratio

Economists often use the ratio of R&D expenditures to GDP to examine R&D in the context of a nation's overall economy. This ratio reflects the intensity of R&D activity in relation to other economic activity and is often interpreted as a relative measure of a nation's commitment to R&D.

Since 1953, the first year for which national R&D data are available, U.S. R&D expenditures as a percentage of GDP have ranged from a minimum of 1.36 percent (in 1953) to a maximum of 2.87 percent (in 1964) (figure 4-5). From 1994 to 2001, R&D outpaced growth of the general economy and the R&D/GDP ratio rose close to its historic high. It is estimated that the amount of R&D performed in the United States equaled 2.71 percent of the United States GDP in 2001 and 2.64 percent in 2002.[8]

Most of the growth over time in the R&D/GDP ratio can be attributed to steady increases in non-Federal R&D spending.[9] Nonfederally financed R&D, the majority of which is company financed, increased from 0.63 percent of GDP in 1953 to an estimated 1.90 percent of GDP in 2002 (down from a high of 2.02 percent of GDP in 2000). The increase in nonfederally financed R&D as a percentage of GDP illustrated in figure 4-5 corresponds to an upward trend in R&D and technology intensive activities in the U.S. economy.

Figure 4-5
R&D share of GDP: 1953–2002



GDP gross domestic product

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* annual series. See appendix tables 4-1 and 4-3.

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Historically, most of the peaks and valleys in the R&D/GDP ratio can be attributed to changing priorities in Federal R&D spending. The initial drop in the R&D/GDP ratio from its peak in 1964 largely reflects Federal cutbacks in defense and space R&D programs. Gains in energy R&D activities between 1975 and 1979 resulted in a relative stabilization of the ratio. Beginning in the late 1980s, cuts in defense-related R&D kept Federal R&D spending from keeping pace with GDP growth, whereas growth in non-Federal sources of R&D spending generally kept pace with or exceeded GDP growth. (See the discussion of defense-related R&D in the next section.)

Sectoral Composition of R&D Performance

Since the early 1980s, R&D performance in some sectors has grown much faster than in others. The industrial sector in particular has grown increasingly dominant (figure 4-1). In 1980, industry performed 68.4 percent of the nation's R&D, the academic sector performed 10.2 percent, laboratories within Federal agencies (Federal intramural R&D) performed 12.4 percent, and the nonprofit sector performed 2.6 percent. All FFRDCs combined performed 6.5 percent of the nation's R&D. Industry's defense-related R&D efforts accelerated in the early 1980s, and its share of R&D performance rose to 71.8 percent in 1985.

From 1985 to 1994, R&D performance grew by only 1.4 percent per year in real terms for all sectors combined. This growth was not evenly balanced across performing sectors, however. R&D performance at universities and colleges grew by 5.4 percent per year in real terms, compared with

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[8] Growth in the R&D/GDP ratio does not necessarily imply increased R&D expenditures. For example, the rise in R&D/GDP from 1978 to 1985 was due as much to a slowdown in GDP growth as it was to increased spending on R&D activities.

[9] Non-Federal sources of R&D tracked by NSF include industrial firms, universities and colleges, nonprofit institutions, and state and local governments.

only 1.0 percent for industry, –0.5 percent for Federal intramural performance, 5.0 percent for nonprofit organizations, and 0.4 percent for all FFRDCs combined.

The 1994–2000 period was one of dramatic changes for these growth rates. Total R&D performance in real terms averaged 5.8 percent growth per year, which was substantially higher than in the earlier sluggish period. Yet, R&D performance at universities and colleges grew at a slower rate of 4.1 percent per year in real terms.[10] Industrial R&D expanded at a remarkable rate of 7.1 percent in real terms (despite a decline in company-reported Federal financing of R&D). Federal intramural performance decreased by 0.3 percent per year in real terms. Nonprofit organizations, according to current estimates, increased their R&D performance by 7.1 percent per year in real terms over the same 6-year period. Finally, R&D performance at all FFRDCs combined declined by 0.1 percent per year in real terms in this period.

Industry is expected to have performed 70.4 percent of the nation's total R&D in 2002 (table 4-1). The estimated $194.4 billion in industrial R&D performance represents a 2.5 percent average annual decrease in real terms from the 2000 level. Of the industrial R&D performed in 2002, 91.2 percent was funded by industry; the remaining 8.8 percent was federally funded. The federally funded share of industry's R&D performance total has fallen considerably from 31.9 percent in 1987.

Universities and colleges are estimated to have performed 13.0 percent ($36.0 billion) of national R&D in 2002, an average annual increase of 6.6 percent in real terms over their share in 2000. The Federal Government performed 8.6 percent ($23.8 billion) of U.S. R&D in 2002, an average annual increase in real terms of 13.3 percent over the 2000–2002 period. All FFRDCs combined performed an estimated $10.3 billion of R&D in 2002, or 3.7 percent of the U.S. total. The nonprofit sector performed an estimated $11.6 billion in 2002, or 4.2 percent of the U.S. total.

Trends in R&D by Character of Work

Because research and development encompasses a broad range of activities, it is helpful to disaggregate R&D expenditures into the traditional categories of basic research, applied research, and development. Despite the difficulties in classifying specific R&D projects, these categories are useful for characterizing the expected time horizons, outputs, and types of investments associated with R&D expenditures.

In 2002 the United States performed an estimated $49.6 billion of basic research, $64.8 billion of applied research, and $161.8 billion of development (table 4-1). As a share of all 2002 R&D expenditures, basic research represented 17.9 percent, applied research represented 23.5 percent, and development represented 58.6 percent.

Basic Research

In 2002, universities and colleges performed 53.8 percent of basic research, more than any other sector. The intellectual freedom and diversity of these institutions make them ideally suited to carry out basic research. Industry performed an estimated 15.6 percent of U.S. basic research in 2002. Rather than serve an immediate market need, the basic research performed by a firm with industry funds serves to strengthen the innovative capacity of the firm by developing human capital and increasing the capability of the firm to absorb external scientific and technological knowledge.

The Federal Government, estimated to have provided 58.9 percent of basic research funding in 2002, historically has provided the majority of funding for basic research (figure 4-6). Moreover, the Federal Government funded 61.8 percent of the basic research performed by universities and colleges in 2002. Industry devoted only an estimated 5 percent of its total R&D support to basic research in 2002, representing 18.5 percent of the national total. The reason for industry's relatively small contribution to basic research is that basic research generally involves the most uncertainty in terms of both the technical success and the commercial value of any results in the three broad categories of R&D. The industries that invest the most in basic research are those whose new products and services are most directly linked to advances in science and engineering, such as the pharmaceuticals industry and the scientific R&D services industry.

Applied Research

Nonacademic institutions perform the majority of U.S. applied research, which totaled $64.8 billion in 2002. Industrial performers accounted for 65.7 percent of all applied research, with the remainder largely performed by Federal laboratories (12.5 percent) and universities and colleges (12.4 percent). Industrial support accounts for 61.5 percent ($39.8 billion) of the 2002 total for applied research and Federal support for 31.6 percent ($20.5 billion). The Federal Government's investment in research has historically emphasized basic research over applied research, reflecting the belief that the private sector is less likely to invest in basic research. In 2002, Federal funding for applied research was 70 percent of that for basic research.

Within industry, applied research acts to refine and adapt existing scientific knowledge and technology into knowledge and techniques useful for creating or improving products, processes, or services. The level of applied research in an industry reflects both the market demand for substantially (as opposed to cosmetically) new and improved goods and services as well as the level of effort required to transition from basic research to technically and economically feasible concepts. Examples of industries that perform a relatively

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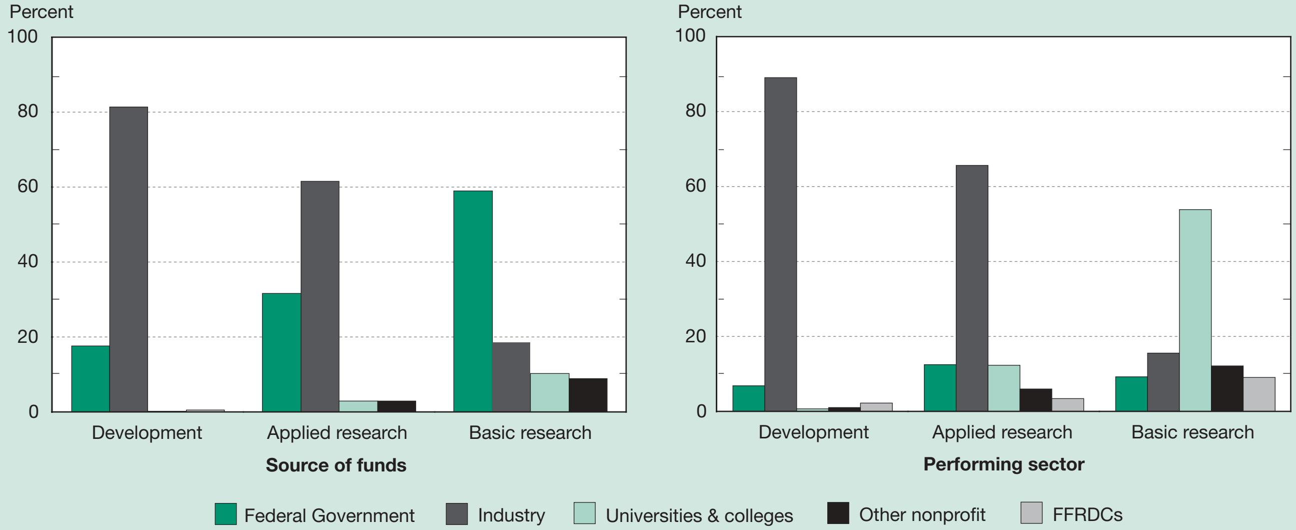
[10] Recent methodological improvements in the estimation of total academic R&D have resulted in a break in the time series. Data for years before 1998 are slightly overstated compared with the data for later years. Had the same methodology been used for all years in the series, the average annual growth rate would have been closer to 4.3 percent per year in real terms from 1994 to 2000. See Machen and Shackelford (forthcoming) for details on the changes to methodology.

Figure 4-6
National R&D expenditure, by source of funds, performing sector, and character of work: 2002



FFRDC federally funded research and development center

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* annual series. See appendix tables 4-7 through 4-18.

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large amount of applied research are the semiconductor industry and the biotechnology industry.

Development

Development expenditures totaled an estimated $161.8 billion in 2002, representing the majority of U.S. R&D expenditures. The development of new and improved goods, services, and processes is dominated by industry, which performed 89.0 percent of all U.S. development in 2002. Federal laboratories and FFRDCs performed an estimated 9.1 percent of U.S. development; the remainder was performed by universities and colleges and nonprofit institutions.

Industry and the Federal Government together funded 99.0 percent of all development in 2002, with industry providing 81.4 percent and the Federal Government providing 17.6 percent. The Federal Government generally invests in the development of such products as tactical nuclear weapons and space exploration vehicles, for which it is the only consumer. The Federal investment in development is dominated by the Department of Defense (DOD), which invests 85 percent of its R&D funds in development (figure 4-7). For more information about Federal R&D funding by agency and character of work, see “R&D by Federal Agency.”

Investments in development differ from investments in basic and applied research in that they are relatively short-term in nature and tend to depreciate in value relatively rapidly.[11] To track its longer-term investments in S&T, the Federal Government excludes much of its spending on development in favor of focusing on basic and applied research and other investments in R&D plant and S&E education. For more information, see “Federal S&T Budget” in “Federal R&D Funding by National Objective.”

Industrial R&D by Industry, Firm Size, and R&D Intensity

The level of industrial R&D is one indicator of industry’s commitment at any point in time to the production of new and improved products, services, and processes. R&D expenditures, like those for advertising, are discretionary and are set by firms at levels intended to maximize future profits. R&D expenditures therefore indicate both the importance that R&D is accorded with respect to other discretionary spending as well as firms’ perceptions of the demand for new and improved technology. Of particular importance is industrial R&D that is financed by the private sector as opposed to the Federal Government. The broad themes explored in this section include the strong rise in industry-funded R&D, the rise of service-sector R&D after the early 1980s, a restructuring of U.S. industrial R&D that is partially related to changes in service-sector R&D trends, and R&D intensities as a tool for industry analysis.

As previously described, R&D performed by private industry reached $194.4 billion in 2002. This total represents a 2.5 percent average annual decline in real terms from the 2000 level of $197.6 billion. Most of this decline was in industry-financed R&D. Companies funded 91.2 percent ($177.3 billion) of their 2002 R&D performance, with the Federal Government funding nearly all the rest ($17.1 billion, or 8.8 percent of the total). For more than a decade the

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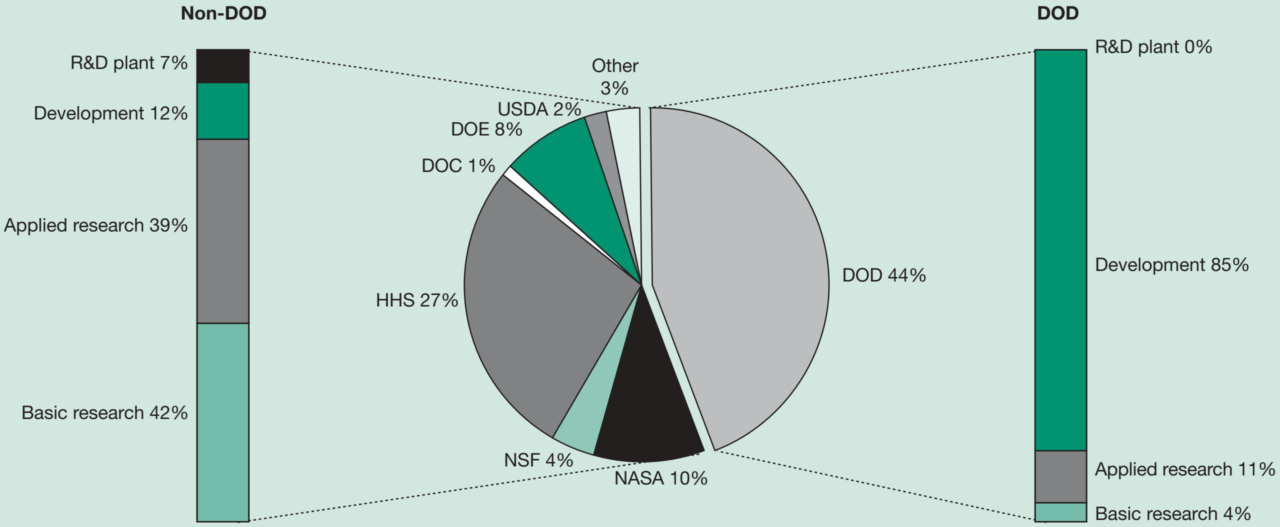
[11] A newly developed product faces eventual obsolescence, whereas discoveries made through basic or applied research tend to be cumulative in nature and provide value for many years.

Figure 4-7
Projected Federal obligations for R&D and R&D plant, by agency and character of work: FY 2003



DOC Department of Commerce; DOD Department of Defense; DOE Department of Energy; HHS Department of Health and Human Services; NSF National Science Foundation; NASA National Aeronautics and Space Administration; USDA Department of Agriculture

NOTE: Percents may not sum to 100 because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2001, 2002, and 2003,* forthcoming. See appendix table 4-32.

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largest component of R&D in the United States has been performed by private industry through private industry's own funds. (Some of this funding is supported through venture capital investments. For a discussion of the relationship between venture capital and R&D expenditures, see chapter 6.) This component of U.S. R&D grew from 43 percent of total R&D in 1953 to 64 percent in 2002.

R&D in Nonmanufacturing Industries

Until the 1980s, little attention was paid to R&D performed by nonmanufacturing companies largely because R&D activity in the service sector was negligible compared with the R&D operations of manufacturing companies. Before 1983, nonmanufacturing industries accounted for less than 5 percent of total industrial R&D performance (including industry-administered FFRDCs), but by 2001 (the most current year for detailed data on industrial R&D), they accounted for 39.2 percent.[12] In 2001, firms classified in nonmanufacturing industries performed $77.8 billion of R&D ($72.4 billion in funds provided by companies and other non-Federal sources and $5.4 billion in Federal support) (table 4-2). Of this amount, 79 percent ($56.9 billion) can be attributed to trade, software and computer-related services, and scientific R&D services.[13] An examination of these three groups of industries helps explain the dramatic growth in nonmanufacturing R&D over the past 2 decades.

R&D performance attributed to the trade industry reached $24.4 billion in 2001. Although some of this R&D was performed by companies whose primary business was wholesale or retail trade, there is little doubt that this sum includes more than just the activities of dot.com retailers. A known consequence of assigning firms to one industry based on payroll data—the classification method used for the NSF Industry R&D Survey—is that a company can be classified in an industry that is not directly related to its reported R&D activities.[14] Although imperfect, this classification scheme reasonably categorizes all but the most diversified companies into industries closely aligned with their primary business activities. The classification of firms into the trade industry is one exception to this assertion because the sale and marketing of goods and services, a trade activity, is often a significant activity in both manufacturing and nonmanufacturing firms. A large pharmaceutical firm or diversified conglomerate would be classified in the trade

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[12] Beginning with the 2001 survey cycle, industry-administered FFRDCs were removed from the industrial R&D statistics. This resulted in a relative increase in the share of R&D performed by nonmanufacturing industries. In 2000, when these FFRDCs were included in the industrial R&D totals, R&D performed by nonmanufacturing industries accounted for 37.8 percent of total industrial R&D.

[13] The trade and scientific R&D services industries are distinct entries in the NSF industrial R&D tables. Software and computer-related services, however, is the sum of three related entries: software, other information, and computer systems design and related services.

[14] Details on how companies are assigned industry codes in the NSF Survey of Industrial Research and Development can be found on the NSF website (http://www.nsf.gov/sbe/srs/nsf02312/sectb.htm#frame). National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2003. Available at http:// www.nsf.gov/sbe/srs/indus/start.htm.

Table 4-2

Industrial R&D performance, by industry and source of funding: 2001

Industry	NAICS code	Total	Federal Government	Company funded	Percent distribution of company-funded
		Millions of dollars			
All industries	21–23, 31–33, 42, 44–81	198,505	16,899	181,606	100.0
Manufacturing	31–33	120,705	11,484	109,221	60.1
Food	311	1,819	0	1,818	1.0
Beverage and tobacco products	312	152	0	152	0.1
Textiles, apparel, and leather	313–16	D	D	255	0.1
Wood products	321	182	0	181	0.1
Paper, printing, and support activities	322, 323	D	D	2,664	1.5
Petroleum and coal products	324	D	D	1,057	0.6
Chemicals	325	17,892	180	17,713	9.8
Basic chemicals	3251	1,876	42	1,835	1.0
Resin, synthetic rubber, fibers, and filament	3252	D	D	2,745	1.5
Pharmaceuticals and medicines	3254	10,137	0	10,137	5.6
Other	325 (minus 3251–52, 3254)	D	D	2,996	1.6
Plastics and rubber products	326	D	D	2,245	1.2
Nonmetallic mineral products	327	990	11	978	0.5
Primary metals	331	485	6	479	0.3
Fabricated metal products	332	1,599	54	1,545	0.9
Machinery	333	6,404	67	6,337	3.5
Computer and electronic products	334	47,079	5,848	41,232	22.7
Computers and peripheral equipment	3341	D	D	3,165	1.7
Communications equipment	3342	15,507	298	15,209	8.4
Semiconductor and other electronic components	3344	14,358	148	14,210	7.8
Navigational, measuring, electromedical, and control instruments	3345	12,947	5,382	7,565	4.2
Other	334 (minus 3341–42, 3344–45)	D	D	1,083	0.6
Electrical equipment, appliances, and components	335	4,980	301	4,680	2.6
Transportation equipment	336	25,965	4,961	21,004	11.6
Motor vehicles, trailers, and parts	3361–63	D	D	16,089	8.9
Aerospace products and parts	3364	7,868	3,785	4,083	2.2
Other	336 (minus 3361–64)	D	D	832	0.5
Furniture and related products	337	301	0	301	0.2
Miscellaneous manufacturing	339	6,606	25	6,581	3.6
Medical equipment and supplies	3391	D	D	5,903	3.3
Other	339 (minus 3391)	D	D	678	0.4
Nonmanufacturing	21–23, 42, 44–81	77,799	5,415	72,384	39.9
Mining, extraction, and support activities	21	D	D	846	0.5
Utilities	22	133	19	114	0.1
Construction	23	320	1	320	0.2
Trade	42, 44, 45	24,372	88	24,284	13.4
Transportation and warehousing	48, 49	1,848	72	1,776	1.0
Information	51	D	D	17,259	9.5
Publishing	511	13,760	44	13,716	7.6
Newspaper, periodical, book, and database	5111	649	0	649	0.4
Software	5112	13,111	44	13,067	7.2
Broadcasting and telecommunications	513	D	D	1,270	0.7
Other	51 (minus 511, 513)	D	D	2,273	1.3
Finance, insurance, and real estate	52, 53	D	D	2,424	1.3
Professional, scientific, and technical services	54	27,704	5,065	22,640	12.5
Architectural, engineering, and related services	5413	3,386	1,021	2,365	1.3
Computer systems design and related services	5415	9,154	498	8,656	4.8
Scientific R&D services	5417	14,244	3,352	10,893	6.0
Other	54 (minus 5413, 5415, 5417)	920	194	726	0.4
Management of companies and enterprises	55	381	0	381	0.2
Health care services	621–23	1,149	29	1,120	0.6
Other	56, 61, 624, 71, 72, 81	1,259	38	1,221	0.7

D data withheld to avoid disclosing operations of individual companies

NAICS North American Industry Classification System

NOTE: Manufacturing companies with fewer than 50 employees and nonmanufacturing companies with fewer than 15 employees were sampled separately without regard to industry classification to minimize year-to-year variation in survey estimates. However, estimates for companies in these groups are included with their respective NAICS classification for this table.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Research and Development in Industry: 2001*, forthcoming. See appendix tables 4-19, 4-20, and 4-21.

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industry if the payroll associated with its sales and marketing efforts outweighed that of any other industrial activity in the company. One indication of these classification artifacts is that in 2001, 86 percent of the R&D attributed to the trade industry was performed by companies with total R&D programs in excess of $100 million, whereas companies in the same size category accounted for only 42 percent of the R&D in all other nonmanufacturing industries combined. Another indication is that more than $1 billion of biotechnology R&D was reported by companies classified in the trade industry in 2001.

Nonmanufacturing industries associated with software and computer-related services such as data processing and systems design performed approximately $24.0 billion of company-funded R&D in 2001.[15] As computing and IT became more powerful, flexible, and ubiquitous over the past 2 decades, the demand for services associated with these technologies boomed. The R&D of companies providing these services also grew dramatically during this period. In 1987, when an upper-bound estimate of software and other computer-related services R&D first became available, companies classified in the industry group "computer programming, data processing, other computer-related, engineering, architectural, and surveying services" performed $2.4 billion of company-funded R&D, or 3.8 percent of all company-funded industrial R&D. In 2001 the company-funded R&D of a comparable group of industries (excluding engineering and architectural services) was greater by a factor of 10 and accounted for 13.2 percent of all company-funded industrial R&D[16] (table 4-3). This trend in the growth of software and computer-related services R&D shows no sign of slowing. Despite essentially no growth in total company-funded, industry-performed R&D between 2000 and 2001, the company-funded R&D for this group of industries grew by 10 percent.

Table 4-3

Estimated share of computer-related services in company-funded R&D and domestic net sales: 1987–2001

(Percent)

Year	Company-funded R&D	Domestic net sales
1987	3.8	1.4
1988	3.6	1.5
1989	3.4	1.4
1990	3.7	1.5
1991	3.6	1.6
1992	4.0	1.6
1993	8.2	1.5
1994	6.6	2.2
1995	8.8	3.3
1996	8.8	2.6
1997	9.1	2.5
1998	9.5	2.2
1999	10.7	2.6
2000	12.1	2.9
2001	13.2	3.5

NOTES: Data before 1998 are for companies classified in Standard Industrial Classification (SIC) industries 737 (computer and data processing services) and 871 (engineering, architectural, and surveying services). For 1998 and later years, data are for companies classified in North American Industry Classification System (NAICS) industries 5112 (software), 51 minus (511, 513) (other information), and 5415 (computer systems design and related services). Using SIC classification, the information technology services share of company-funded R&D is 10.4 percent for 1998, indicating that SIC-based data are overestimates of actual information technology services R&D and net sales.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, special tabulations (Arlington, VA, 2003).

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The R&D performed by companies in the scientific R&D services industry more than doubled in the 4 years between 1997 and 2001 from $7.0 to $14.2 billion.[17] The portion of this industry's R&D that was company-funded increased at an even faster pace, from $4.7 billion in 1997 to $10.9 billion in 2001. The scientific R&D services industry comprises companies that specialize in conducting R&D for other organizations, such as many biotechnology companies. (See sidebar, "Biotechnology R&D in Industry.") Although these companies and their R&D activities are classified as nonmanufacturing because they provide business services, many of the industries they serve are manufacturing industries. This implies that the R&D activities of a research firm that services a manufacturer would have been classified as R&D in manufacturing if the same research firm were a subsidiary of the manufacturer. Consequently, a growth in measured R&D in services may, in part, "reflect a more general pattern of industry's increasing reliance on outsourcing and contract R&D" (Jankowski 2001). (For more information, see "Contract R&D.")

Although a great deal of R&D in the United States is related in some way to health care services, companies specifically categorized in the health care services sector accounted for only 0.4 percent of all industrial R&D and for only 1.0 percent of all R&D by nonmanufacturing companies. As in many industries, innovation often results from R&D performed in other industries, in this case the pharmaceutical, scientific instrument, and software industries in particular. These results illustrate that R&D data disaggregated according to industrial categories (including the distinction between manufacturing and nonmanufacturing industries) may not always reflect the relative proportions of R&D devoted

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[15] Although disclosure of Federal R&D funding prohibited the precise tabulation of total R&D performance for this industry, total R&D was between $24.5 billion and $24.6 billion.

[16] The introduction of a more refined industry classification scheme in 1999 allowed more detailed reporting in nonmanufacturing industries. For the cited 2001 statistic, the R&D of companies in software, other information, and computer systems design and related services industries were combined. These three industries provided the closest approximation to the broader category cited for earlier years without exceeding the coverage of the broader category.

[17] The 1997 data for this industry are bridged from a different industry classification scheme.

Biotechnology R&D in Industry

Of particular interest to researchers, investors, and policymakers are the R&D activities of companies in emerging, fast-growing sectors of science and technology such as biotechnology. Unfortunately, the rapidly evolving and often multidisciplinary nature of these sectors makes them very difficult to track as unique industry categories. In 2001, for the first time, NSF collected data on industrial R&D for biotechnology and other select technology areas on its NSF Survey of Industrial Research and Development (only companies with estimated total R&D of at least $5 million in 2000 were asked to report R&D by technology area in 2001). Although many companies were unable or unwilling to report their R&D activities by technology area, the data reported reveal much about the structure of biotechnology R&D in the United States. As table 4-4 illustrates, the scientific R&D services industry accounted for slightly more than half of the reported $7.4 billion of biotechnology R&D. Many biotechnology firms that perform contract R&D for pharmaceutical companies are classified as part of this industry. Biotechnology R&D accounts for at least a fourth of all R&D in this industry and accounted for at least 3.7 percent of total U.S. industrial R&D in 2001. The $1.1 billion of biotechnology R&D reported in the trade industry is predictable from the activities of pharmaceutical firms, which devote considerable resources to marketing and selling their products. The data suggest that smaller firms, on average, are more likely to perform biotechnology R&D than other industrial R&D; companies with fewer than 5,000 employees performed three-fourths of the reported biotechnology R&D, whereas companies in this size bracket performed only 38 percent of total industrial R&D in 2001.

Table 4-4
Total R&D and lower bound biotechnology R&D by industry and company size: 2001

Industry and company size	R&D Total	R&D Biotechnology	Biotechnology/ total R&D
	Millions of dollars		Percent
All industries	198,505	7,350	3.7
Manufacturing	120,705	2,193	1.8
Pharmaceuticals and medicines	10,137	1,882	18.6
Nonmanufacturing	77,799	5,157	6.6
Trade	24,372	1,104	4.5
Scientific R&D services	14,244	3,846	27.0
Company size (number of employees), total	198,505	7,350	3.7
5–24	4,828	0	0.0
25–49	3,750	118	3.1
50–99	8,202	398	4.9
100–249	12,916	869	6.7
250–499	8,702	533	6.1
500–999	10,564	1,300	12.3
1,000–4,999	26,748	2,155	8.1
5,000–9,999	17,487	D	D
10,000–24,999	27,065	149	0.6
25,000 or more	78,244	D	D

D data withheld to avoid disclosing operations of individual companies

NOTES: Details may not add to totals because of rounding. Data for biotechnology R&D are underestimated because no attempt was made to correct for item nonresponse. Counts of respondents suggest that actual figures could be much larger. Also, these totals exclude biotechnology R&D of firms whose total R&D was less than $5 million in 2000. These firms were not asked to report their biotechnology R&D separately on 2001 survey form. This is probably the main reason firms with 5–24 employees have no reported biotechnology R&D.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2001.

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Table 4-5
Funds for industry R&D performance and number of R&D-performing companies in manufacturing and nonmanufacturing industries, by size of company: 2001

	Funds			Companies		
Company size	Total	Manufacturing	Non-manufacturing	Total	Manufacturing	Non-manufacturing
	Millions of dollars			Number		
Total (number of employees)	198,505	120,705	77,799	33,263	16,817	16,446
5–25	4,828	973	3,855	14,681	5,802	8,879
25–49	3,750	1,123	2,627	5,036	2,013	3,023
50–99	8,202	3,924	4,278	5,030	3,209	1,820
100–249	12,916	4,817	8,099	4,261	2,817	1,444
250–499	8,702	3,345	5,357	1,504	1,040	464
500–999	10,564	5,290	5,273	1,194	851	343
1,000–4,999	26,748	15,828	10,919	1,039	755	284
5,000–9,999	17,487	10,918	6,569	244	164	80
10,000–24,999	27,065	15,647	11,418	156	97	60
25,000 or more	78,244	58,840	19,404	118	68	50

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Research and Development in Industry: 2001* (Arlington, VA, forthcoming).

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to particular types of scientific or engineering objectives or to particular fields of science or engineering.

R&D in Manufacturing Industries

Within the manufacturing industries, three groups dominate: computer and electronic products, transportation equipment, and chemicals (table 4-2). In 2001, computer and electronic products accounted for the largest amount of R&D performed among all industries at $47.1 billion, or 23.7 percent of all industrial R&D and 39.0 percent of all manufacturing R&D. For this subsector, industrial firms provided $41.2 billion in R&D support and the Federal Government funded the remainder.

In 2001, transportation equipment accounted for the second most R&D performed in the manufacturing sector at $26.0 billion, or 13.1 percent of all industrial R&D. Of these expenditures, 19.1 percent was federally funded, primarily for R&D on aerospace products (planes, missiles, and space vehicles). In addition to aerospace products, this subsector includes a variety of other forms of transportation equipment, such as motor vehicles, ships, military armored vehicles, locomotives, and smaller vehicles such as motorcycles, bicycles, and snowmobiles.

In 2001, chemicals ranked third in R&D performed in the manufacturing subsector at $17.9 billion, approximately 1 percent of which was federally funded. In terms of R&D performance, the largest industry within the chemicals subsector is pharmaceuticals and medicines. In 2001, R&D performed by these companies accounted for 61 percent of non-Federal R&D funding in the chemicals subsector ($12.9 billion).

Industrial R&D and Firm Size

Manufacturing R&D performers are typically quite different from nonmanufacturing R&D performers. Manufacturing R&D performers tend to be larger firms that perform more R&D on average than nonmanufacturing firms (table 4-5). Approximately 33,000 firms in the United States performed R&D in 2001; of these, 51 percent were in the manufacturing sector. Manufacturers account for an even greater share (61 percent) of total industrial R&D performance. As a share of the nation's GDP, on the other hand, manufacturing contributes less than 20 percent. Manufacturers dominate in terms of R&D performance largely because of the activities of the largest manufacturing firms. In 2001 the largest manufacturing firms (those with 25,000 or more employees) accounted for 49 percent of the R&D in the manufacturing sector, whereas nonmanufacturing firms in the same size category accounted for only 25 percent of total nonmanufacturing R&D.[18]

Among small R&D-performing firms (those with less than 500 employees), those in the nonmanufacturing sector conduct significantly more R&D than those in the manufacturing sector, both in aggregate and on a per-firm basis. These small firms accounted for 12 percent of manufacturing R&D, 31 percent of nonmanufacturing R&D, and 19 percent of all industrial R&D in 2001.

Although R&D tends to be performed by large firms in the manufacturing sector and smaller firms in the nonmanufacturing sector, considerable variation can be found within each sector, depending on the type of industry. R&D tends to be conducted primarily by large firms in several industrial

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[18] R&D performance is even more skewed towards companies with large R&D programs (total R&D of $100 million or more). The 243 firms in this category accounted for 73 percent of manufacturing R&D, 56 percent of nonmanufacturing R&D, and 67 percent of all industrial R&D in 2001.

subsectors: aircraft and missiles; electrical equipment; professional and scientific instruments; transportation equipment (not including aircraft and missiles); and transportation and utilities, which are in the nonmanufacturing sector. In these same sectors, however, much of the economic activity occurs in large firms to begin with, so the observation that most of the R&D in these sectors is also conducted by large firms is not surprising.

R&D Intensity

In addition to absolute levels of and changes in R&D expenditures, another key indicator of industrial commitment to S&T is R&D intensity, a measure of R&D relative to production in a company, industry, or sector. For most firms, R&D is similar to sales, marketing, and general management expenses because it is a discretionary expense. R&D does not directly generate revenue in the same way that production expenses do, so it can be trimmed when profits fall. Evidence suggests, however, that R&D enjoys some degree of immunity from belt-tightening endeavors, even when the economy is faltering, because of its crucial role in laying the foundation for future growth and prosperity.

Many ways exist to measure R&D intensity; the one used most frequently is the ratio of company-funded R&D to net sales.[19] This statistic provides a way to gauge the relative importance of R&D across industries and among firms in the same industry. The industrial subsectors with the highest R&D intensities in 2001 were scientific R&D services (36.5 percent), software (19.3 percent), communications equipment (16.6 percent), and computer systems design and related services (16.5 percent). The R&D intensities of the professional, scientific, and technical services industries are particularly high because, as previously explained, much of the R&D reported by these companies also appears in their reported sales figures. Industries with the lowest R&D intensities (0.5 percent or less) were food, broadcasting and telecommunications, and utilities (table 4-6). A decrease in the net sales of R&D-performing companies between 2000 and 2001 resulted in the ratio of R&D to sales for all industries increasing to 3.8 percent in 2001, up from 3.4 percent in 2000.

Sales are more skewed towards larger companies than R&D performance (table 4-6). Smaller companies have much larger R&D-to-sales ratios than larger companies, reflecting that most startups and companies with less established revenue streams tend to be smaller. Large, well-established companies often have reserves of cash and other liquid assets that allow them to maintain their R&D activities amid short-term economic downturns. Less mature companies,

Table 4-6
Company and other (non-Federal) R&D fund share of net sales in R&D-performing companies, by industry and company size: 2000, 2001
(Percent)

Industry and company size	2000	2001
All industries	3.4	3.8
Manufacturing	3.3	3.6
Communications equipment	10.1	16.6
Semiconductor and other electronic components	7.4	10.5
Medical equipment and supplies	12.9	9.0
Pharmaceuticals and medicines	9.6	7.8
Computers and peripheral equipment	6.4	7.6
Navigational, measuring, electromedical, and control instruments	8.0	7.3
Resin, synthetic rubber, fibers, and filament	5.6	4.5
Machinery	3.8	4.2
Motor vehicles, trailers, and parts	3.2	3.5
Other chemicals	3.8	3.2
Aerospace products and parts	2.8	3.0
Electrical equipment, appliances, and components	2.2	2.9
Plastics and rubber products	1.4	2.9
Nonmetallic mineral products	1.8	2.3
Basic chemicals	2.3	2.2
Paper, printing, and support activities	1.6	2.1
Fabricated metal products	1.5	1.6
Furniture and related products	0.8	0.9
Primary metals	0.5	0.7
Food	0.4	0.5
Nonmanufacturing	3.8	4.0
Scientific R&D services	34.4	36.5
Software	20.4	19.3
Computer systems design and related services	15.8	16.5
Management of companies and enterprises	4.4	7.8
Trade	5.4	6.2
Architectural, engineering, and related services	7.3	5.2
Health care services	3.2	4.1
Newspaper, periodical, book, and database	2.0	2.7
Transportation and warehousing	0.3	2.4
Construction	1.8	1.4
Mining, extraction, and support activities	1.2	1.3
Finance, insurance, and real estate	1.2	0.7
Broadcasting and telecommunications	0.4	0.5
Utilities	0.1	0.0
Company size (number of employees)		
5–24	17.2	12.9
25–49	13.4	10.6
50–99	11.2	10.4
100–249	8.0	10.8
250–499	6.1	8.0
500–999	4.7	5.7
1,000–4,999	3.5	4.2
5,000–9,999	2.2	2.5
10,000–24,999	3.1	3.5
25,000 or more	2.9	3.0

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Research and Development in Industry: 2001* (Arlington, VA, forthcoming).

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[19] A similar measure of R&D intensity is the ratio of R&D to *value added* (sales minus the cost of materials). Value added is often used in studies of productivity because it allows analysts to focus on the economic output attributable to the specific industrial sector in question by subtracting materials produced in other sectors. For a discussion of the connection between R&D intensity and technological progress, see, for example, R. Nelson, Modeling the connections in the cross section between technical progress and R&D intensity, *RAND Journal of Economics* 19(3) (Autumn 1988): 478–485.

however, tend to be more reliant on outside investment and thus their expenditures on R&D are more likely to be cut in the event of a contraction in the economy or capital markets. This is one explanation for the divergence in the R&D intensities of very small companies (less than 100 employees) and all other companies between 2000 and 2001.

R&D Expenses of Public U.S. Corporations

Most firms that make significant investments in R&D track their R&D expenses separately in their accounting records. (See sidebar, "R&D: Asset or Expense?") The annual reports of public U.S. corporations often include data on these R&D expenses.[20] In 2001 the 20 U.S. corporations with the largest reported R&D expenditures spent $67.9 billion on R&D. Ford Motor Company reported the most R&D ($7.4 billion), followed by General Motors Corporation ($6.2 billion) (table 4-7). IT companies and pharmaceutical companies dominate the remainder of the list.

Corporate data tabulated by the U.S. Department of Commerce (DOC) reveal that the R&D spending of U.S.-headquartered corporations grew from $93.6 billion in 1994 to $164.5 billion in 2000, implying average annual real growth of 7.9 percent over the period (U.S. DOC/TA 2002). The largest and fastest growing R&D sectors during this period were the information and electronics manufacture and services sector, which spent $35.3 billion on R&D in 1994 and $77.7 billion in 2000, and the medical substances and devices sector, which spent $16.7 billion in 1994 and $32.5 billion in 2000 (appendix table 4-22). Preliminary analysis of more recent company records indicates that the growth of U.S. corporate R&D slowed in 2001. (See sidebar, "Corporate R&D Strategies in an Uncertain Economy," for information on how some U.S.-based corporations intended to adjust their R&D policies in 2003.)

R&D Performance by State

The latest data available on the state distribution of R&D performance are for 2000. Although R&D expenditures are concentrated in relatively few states, patterns of R&D activities vary considerably among the top R&D-performing locations. In 2000, total U.S. R&D expenditures were $265 billion, of which $247 billion could be attributed to expenditures within individual states, with the remainder falling under an undistributed "other/unknown" category[21] (appendix tables 4-23 and 4-24). These totals include R&D performed by industry, universities, Federal agencies, and nonprofit organizations. (For a broader range of indicators of state-level S&E activities, see chapter 8.)

R&D: Asset or Expense?

Recently economists at the U.S. Bureau of Economic Analysis (BEA) explored the effect on gross domestic product (GDP) of treating R&D as an investment in the National Income and Product Accounts (Fraumeni and Okubo 2002). Given reasonable assumptions regarding the rates of return on R&D and R&D depreciation, the economists reached the following conclusions:

- R&D accounted for approximately 13 percent of GDP growth between 1961 and 2000. Capitalizing R&D increased the rate of growth of GDP by 0.1 percentage point.
- Capitalizing R&D raised the national savings rate (the portion of the national product not devoted to consumption) by 2 percentage points, from 19 to 21 percent.
- Returns to R&D capital represented 19 percent of property-type income. Property-type income largely consists of corporate profits, proprietors' income, net interest, capital consumption allowances, and rental income of persons.

Current financial accounting standards dictate that firms expense R&D expenditures as they occur. But even though accountants do not show the value of R&D on the balance sheet as they do for plant and equipment, analysts have recognized that in theory R&D should be treated as an investment rather than as an expense when valuing a firm (Brealey and Myers 1996; and Lev 2001) or measuring national economic activity (Nakamura 2001). The reasoning for this is that even though the primary output of R&D—knowledge—is intangible, it has a very real impact on future production (new goods and services) and productivity. Thus failing to account for R&D as an "intangible asset" leads to the underestimation of national assets and consequently national production capabilities.

Distribution of R&D Expenditures Among States

In 2000 the 20 highest ranking states in R&D expenditures accounted for 87 percent of U.S. R&D expenditures, whereas the 20 lowest ranking states accounted for only 4 percent. The six states with the highest levels of R&D expenditures (in decreasing order of magnitude) were California, Michigan, New York, New Jersey, Massachusetts, and Illinois, and they accounted for half of the entire national effort. The top 10 states, which included Texas, Washington, Pennsylvania, and Maryland (ranked 7th, 8th, 9th, and 10th,

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[20] This source of R&D data differs from the NSF Survey of Industrial Research and Development, so direct comparisons of these sources are not possible. See C. Shepherd and S. Payson, *U.S. R&D Corporate R&D* (Washington, DC: National Science Foundation, 2001) for an explanation of the differences between the two.

[21] Approximately two-thirds of the R&D that could not be associated with a particular state was R&D performed by the nonprofit sector.

Table 4-7
Top 20 R&D-spending corporations: 2001

	R&D rank			R&D (millions of dollars)			Percent change from		NAICS
Corporation	2001	2000	1999	2001	2000	1999	1999 to 2001	Description	code
Ford Motor Company	1	1	1	7,400	6,800	7,100	4.2	Motor vehicle manufacturing	3361
General Motors	2	2	2	6,200	6,600	6,800	–8.8	Motor vehicle manufacturing	3361
Pfizer Inc.	3	4	8	4,847	4,435	2,776	74.6	Pharmaceutical and medicine manufacturing	3254
International Business Machines	4	5	4	4,620	4,336	4,464	3.5	Computer systems design and related services	5415
Microsoft	5	8	7	4,379	3,775	2,970	47.4	Software publishers	5112
Motorola	6	3	5	4,318	4,437	3,438	25.6	Communications equipment manufacturing	3342
Cisco Systems	7	11	20	3,922	2,704	1,594	146.0	Computer and peripheral equipment manufacturing	3341
Intel	8	7	6	3,796	3,897	3,111	22.0	Semiconductor and other electronic component manufacturing	3344
Johnson & Johnson	9	9	9	3,591	2,926	2,600	38.1	Pharmaceutical and medicine manufacturing	3254
Lucent Technologies	10	6	3	3,520	4,018	4,510	–22.0	Computer systems design and related services	5415
Hewlett-Packard	11	12	10	2,635	2,646	2,440	8.0	Computer and peripheral equipment manufacturing	3341
Merck & Company	12	13	11	2,456	2,344	2,068	18.8	Pharmaceutical and medicine manufacturing	3254
Bristol Myers Squibb	13	15	12	2,259	1,939	1,843	22.6	Pharmaceutical and medicine manufacturing	3254
Lilly (Eli) and Company	14	14	13	2,235	2,019	1,784	25.3	Pharmaceutical and medicine manufacturing	3254
Pharmacia	15	10	25	2,195	2,753	1,290	70.2	Pharmaceutical and medicine manufacturing	3254
Sun Microsystems	16	22	26	2,016	1,630	1,263	59.7	Computer and peripheral equipment manufacturing	3341
General Electric	17	17	17	1,980	1,867	1,667	18.8	Engine, turbine, and power transmission equipment manufacturing	3336[a]
Boeing	18	24	22	1,936	1,441	1,341	44.4	Aerospace product and parts manufacturing	3364
Wyeth	19	21	14	1,870	1,688	1,740	7.5	Pharmaceutical and medicine manufacturing	3254
Procter & Gamble	20	16	15	1,769	1,899	1,726	2.5	Soap, cleaning compound, and toilet preparation manufacturing	3256

NAICS North American Industry Classificaiton System

[a] General Electric is classified in Compustat as a conglomerate (NAICS code 9999). For the purpose of this analysis, the industry classification of General Electric's largest manufacturing business segment in 2001 in terms of sales was used.

SOURCE: Standard & Poor's COMPUSTAT database (Englewood, CO, 2003).

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respectively), accounted for two-thirds of U.S. R&D expenditures in 2000 (table 4-8). California alone accounted for more than one-fifth of the $247 billion U.S. R&D total, exceeding the next highest state by nearly a factor of three.[22]

Ratio of R&D to Gross State Product

States vary significantly in the size of their economies because of differences in population, land area, infrastructure, natural resources, and history. Consequently, state variations in R&D expenditure levels may simply reflect differences in economic size or the nature of their R&D efforts. One way to control for the size of each state's economy is to measure each state's R&D level as a percentage of its gross

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[22] Reliability of the estimates of industrial R&D varies by state because the sample for the NSF Survey of Industrial Research and Development was not based on geography. Rankings do not take into account the margin of error of estimates from sample surveys. National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2003. Available at http://www.nsf.gov/sbe/srs/indus/start.htm.

Corporate R&D Strategies in an Uncertain Economy

For the past 19 years the Industrial Research Institute (IRI), a nonprofit association of more than 200 leading R&D-performing industrial companies, has surveyed its U.S.-based members on their intentions for the coming year with respect to R&D expenditures, effort allocation, personnel, and other items. Because IRI member companies carry out as much as three-fourths of the industrial R&D in the United States, the results from these surveys help identify broad trends in corporate R&D strategies. The most recent survey, administered in late 2002, suggests that many companies are shifting the focus of their R&D spending from directed basic research and support of existing business to new business projects (IRI 2003). This reported shift in R&D priorities also is reflected in how responding companies intend to spend their R&D budgets. In 2003, IRI survey respondents reported the following strategic shifts:

- Decreased outsourcing of R&D to other companies
- Increased outsourcing for university R&D and Federal laboratories
- Increased participation in alliances and joint R&D ventures
- Increased acquisition of technology capabilities through mergers and acquisitions

Overall, these strategic moves are consistent with responses suggesting tighter R&D budgets and lower targets for R&D/sales ratios. In the midst of an uncertain economy and technology market, companies are moving to leverage the value of their R&D spending through alliances and collaborations as opposed to contracting out their R&D to other companies. (For more information, see “Technology Linkages: Contract R&D, Federal Technology Transfer, and R&D Collaboration.”)

state product (GSP).[23] Like the ratio of industrial R&D to net sales, the proportion of a state’s GSP devoted to R&D is an indicator of R&D intensity. A list of states and corresponding R&D intensities can be found in appendix table 4-25.

Sector Distribution of R&D Performance by State

Although leading states in total R&D tend to be well represented in each of the major R&D-performing sectors, the proportion of R&D performed in each of these sectors varies across states. States that are national leaders in total R&D performance are usually leaders in R&D performance by industrial sector, which is not surprising because industry-performed R&D accounts for 77 percent of the distributed U.S. total. Although university-performed R&D accounts for only 12 percent of the U.S. total, it also is highly correlated with the total R&D performance in a state.

Less overlap is reported between the top 10 states for total R&D and the top 10 states for federally performed R&D.[24] Only 4 states are in both top 10 lists: Maryland, California, Texas, and New Jersey. Maryland ranked first in Federal R&D performance, followed by the District of Columbia, California, and Virginia. The inclusion of Maryland, Virginia, and the District of Columbia in the top four ranking reflects the concentration of Federal facilities and administrative offices within the national capital area. Alabama, Florida, and New Mexico rank among the highest in Federal R&D because of their relatively high shares of Federal space- and defense-related R&D.

Industrial R&D in Top States

The types of companies that carry out R&D vary considerably among the 10 leading states in industry-performed R&D (table 4-9). This reflects regional specialization or clusters of industrial activity. For example, in Michigan the transportation equipment industry accounted for 73 percent of industrial R&D in 2000, whereas it accounted for only 15 percent of the nation’s total industrial R&D. Washington, having a high concentration of software R&D, has less of its industrial R&D concentrated in manufacturing industries than the nation as a whole. The computer and electronic products industry accounts for 24 percent of the nation’s total industrial R&D but accounts for a larger share of the industrial R&D in California (36 percent), Massachusetts (44 percent), and Texas (42 percent). These three states have clearly defined regional centers of high-technology research and manufacturing: Silicon Valley in California, Route 128 in Massachusetts, and the Silicon Hills of Austin in Texas. In addition, New Jersey and Pennsylvania, both home to robust pharmaceutical and chemical manufacturing industries, show much higher concentrations of R&D in these industries than the nation as a whole. Of course other factors besides the location of industrial production also play a role in the location of industrial R&D activities. For example, industries tend to perform research near universities that conduct the same type of research, enabling them to benefit

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[23] Gross state product (GSP) is often considered the state counterpart of the nation’s GDP. GSP is estimated by summing the *value added* of each industry in a state. Value added for an industry is equivalent to its gross output (sales or receipts and other operating income, commodity taxes, and inventory change) minus its intermediate inputs (consumption of goods and services purchased from other U.S. industries or imported). U.S. Bureau of Economic Analysis, *Gross State Product: New Estimates for 2000 and Revised Estimates for 1998–1999* (Washington, DC, 2002). (See http://www.bea.gov/bea/newsrel/gspnewsrelease.htm.)

[24] Federally performed R&D includes costs associated with the administration of intramural and extramural programs by Federal personnel as well as actual intramural performance.

Table 4-8
Top 10 states in R&D performance, R&D by sector, and R&D as percentage of gross state product: 2000

				States with highest R&D performance, by sector		R&D intensity (highest R&D/GSP ratio)		
Rank	State	Total R&D[a] (millions of current dollars)	Industry[b]	U&C[c]	Federal Government[d]	State	R&D/GSP (percent)	GSP (billions of current dollars)
1	California	55,093	California	California	Maryland	Michigan	5.81	325.4
2	Michigan	18,892	Michigan	New York	District of Columbia	New Mexico	5.68	54.4
3	New York	13,556	New Jersey	Texas	California	Washington	4.78	219.9
4	New Jersey	13,133	Illinois	Pennsylvania	Virginia	Maryland	4.64	186.1
5	Massachusetts	13,004	New York	Maryland	Alabama	Massachusetts	4.56	284.9
6	Illinois	12,767	Massachusetts	Massachusetts	Ohio	Delaware	4.22	36.3
7	Texas	11,552	Washington	Illinois	Florida	Rhode Island	4.12	36.5
8	Washington	10,516	Texas	North Carolina	Texas	California	4.10	1,344.6
9	Pennsylvania	9,842	Pennsylvania	Michigan	New Jersey	Idaho	3.87	37.0
10	Maryland	8,634	Ohio	Georgia	New Mexico	District of Columbia	3.87	59.4

FFRDC federally funded research and development center
GSP gross state product
U&C universities and colleges

[a] Includes in-state total R&D performance of industry, universities, Federal agencies, FFRDCs, and federally financed nonprofit R&D.
[b] Includes R&D activities of industry-administered FFRDCs located within these states.
[c] Excludes R&D activities of university-administered FFRDCs located within these states.
[d] Includes costs associated with administration of intramural and extramural programs by Federal personnel and actual intramural performance.

NOTES: Reliability of estimates of industry R&D varies by state because sample allocation was not based on geography. Rankings do not take into account margin of error of estimates from sample surveys.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, VA, annual series); U.S. Bureau of Economic Analysis, U.S. Department of Commerce, 2002, http://www.bea.gov/bea/newsrel/gspnewsrelease.htm.

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Table 4-9
Top 10 states in industry R&D performance and share of R&D by selected industries: 2000

		Share of total industry-performed R&D				
		Manufacturing industries				
State	Industry-performed R&D[a]	Total	Computer and electronic products	Transportation equipment	Chemicals	Professional, scientific, and technical services
	Millions of current dollars	Percent				
Total	199,539	62.2	22.6	15.1	10.5	11.3
California	45,769	54.1	36.0	7.0	2.9	18.0
Michigan	17,640	88.9	2.0	73.4	6.5	4.7
New Jersey	12,062	61.9	27.6	1.0	25.1	5.6
Illinois	10,661	59.8	26.6	2.5	17.0	2.7
New York	10,539	65.6	16.4	14.7	18.7	3.7
Massachusetts	9,863	59.7	43.5	D	7.7	21.0
Washington	9,265	32.9	5.7	D	D	11.4
Texas	8,961	58.3	42.2	1.5	5.3	7.0
Pennsylvania	7,873	68.5	14.6	4.5	32.9	7.2
Ohio	5,962	65.6	3.0	7.9	D	20.1
All other states	60,946	64.7	17.1	14.5	12.0	10.9

D data withheld to avoid disclosing operations of individual companies

[a] Includes company and federally financed R&D activities and R&D activities of industry-administered federally funded research and development centers (FFRDCs) located within these states.

NOTES: Reliability of the estimates of industry R&D varies by state because sample allocation was not based on geography. Rankings do not take into account margin of error of estimates from sample surveys. Details may not add to totals because not all industries are shown.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2000.

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from local academic resources. (For more information, see "Technology Linkages: Contract R&D, Federal Technology Transfer, and R&D Collaboration.")

Federal R&D Performance and Funding

When Nelson (1959) and Arrow (1962) first laid out their seminal economic arguments that the private sector generally invests less than the socially optimal amount in R&D, the Federal Government funded almost twice as much R&D as did the private sector. Since then these relative positions have reversed, but the argument in support of public funding for R&D is still valid more than 40 years later. Briefly, the argument is that the returns on investment in R&D cannot be fully appropriated by an investor because of the very nature of the primary output of R&D: knowledge. This being the case, firms will only invest in those R&D projects from which, through secrecy, patents, or some other means, they are able to recoup their investment plus an acceptable profit. The government endeavors to correct this market failure through a number of policy measures, the most direct of which is the funding and performance of R&D that would not or could not be financed or performed in the private sector. Thus, despite its declining share in total R&D funding, the Federal Government still supports the majority of basic research in the United States. This section examines the Federal Government's role in performing, funding, and stimulating R&D in the private sector through tax policy.

Federal R&D Performance

Federal laboratories and FFRDCs performed $34.1 billion of total U.S. R&D in 2002, an average annual increase in real terms of 10.4 percent from the 2000 level of $27.1 billion. Among individual agencies, DOD continued to perform the most intramural R&D and is expected to account for more than half of all Federal obligations for intramural R&D in the future. In fiscal year 2003, DOD is expected to perform more than twice the R&D of the second largest R&D-performing agency, the Department of Health and Human Services (HHS), which performs most of its intramural R&D at the National Institutes of Health (NIH) (table 4-10).

The Department of Energy (DOE) sponsors the most FFRDCs of any agency—16 of the 36. These 16 FFRDCs performed a total of $7.5 billion of R&D in FY 2001, approximately three-fourths of all the R&D performed by FFRDCs (appendix table 4-26). First established during World War II, FFRDCs are unique organizations that help the United States government meet special long-term research or development goals that cannot be met as effectively by in-house or contractor resources. (See sidebar, "Rationales for Federal Laboratories and FFRDCs.") According to the *Federal Register,* an FFRDC is required "to operate in the public interest with objectivity and independence, to be free from organizational conflicts of interest, and to have full disclosure of its affairs to the sponsoring agency" (NARA 1990). Total R&D performed by all FFRDCs (estimated at $10.3 billion in 2002) has grown at a real annual rate of 4.5 percent from its level of $9.1 billion in 2000.

Federal R&D Funding by National Objective

In 2002 the Federal Government funded approximately twice as much R&D as that performed in Federal labs and FFRDCs. This support is estimated to be $78.2 billion, reflecting a 6.7 percent average real increase per year since 2000. This funding supports a wide range of national objectives (also termed *budget functions*); is administered by many Federal agencies; and flows to R&D performers in all sectors, from industry to universities and colleges and to nonprofit organizations.

Defense-Related R&D

Defense-related R&D, as a proportion of the nation's total R&D, has shifted substantially. From 53.6 percent in 1959, it declined to a relative low of 24.3 percent in 1980, climbed to 31.7 percent by 1987, and, coinciding with the end of the cold war, fell substantially afterward, reaching a low of 13.5 percent in 2000 (figure 4-8).[25] Despite this dramatic decline relative to nondefense R&D, the absolute level of defense R&D in 2000 still exceeded that in any year from 1953 to 1982, after adjusting for inflation. In 2000, defense-related R&D as a share of U.S. R&D began to grow again, subsequently reaching 14.9 percent of the nation's total R&D in 2002.

In 1980 the Federal budget authority for defense-related R&D was roughly equal to that for nondefense R&D[26] (figure 4-9). Although the amount of defense-related R&D has fluctuated based on changing national security concerns over the past 20 years, nondefense R&D has increased since 1983. For FY 2001 the budget authorities for defense R&D and for nondefense R&D had nearly reached parity at $45.7 and $41.0 billion, respectively. The terrorist attacks of September 11, 2001, dramatically reversed this trend and in the proposed FY 2004 budget, $66.8 billion is slated for defense-related R&D and $51.2 billion is reserved for nondefense R&D. (See sidebar, "Federal R&D for Countering Terrorism.") These amounts reflect increases of 46.2 percent in defense-related R&D and 24.7 percent in nondefense R&D over the FY 2001 levels.

Civilian-Related R&D

R&D accounts for 13.4 percent of the FY 2004 Federal nondefense discretionary budget authority of $383.0 billion.[27] Although this is less than that reserved for defense

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[25] These shares represent a distribution of performer-reported R&D data. They are distinct from the budget authority shares reported subsequently, which are based on the various functional categories constituting the Federal budget.

[26] R&D budget authority data represent a distribution of Federal source-reported data as opposed to performer-reported data.

[27] Most of the $2.2 trillion Federal budget is reserved for mandatory items such as Social Security, Medicare, pension payments, and payments on the national debt. See appendix table 4-30 for historical data on Federal outlays and R&D.

Table 4-10
Federal R&D obligations, total, intramural, and FFRDCs, by U.S. agency: FY 2003

Agency	Total R&D obligations	Intramural[a]	FFRDC	Agency intramural and FFRDC R&D obligations
	Millions of dollars			Percent of total
All Federal Government	98,608.1	24,557.7	7,534.6	32.5
Department of Defense	45,011.7	12,409.0	851.3	29.5
Department of Health and Human Services	27,551.1	5,162.4	403.9	20.2
National Aeronautics and Space Administration	8,598.3	2,149.6	1,405.3	41.3
Department of Energy	7,540.7	764.4	4,609.3	71.3
National Science Foundation	3,403.6	19.4	197.5	6.4
Department of Agriculture	1,984.3	1,367.2	0.0	68.9
Department of Commerce	1,064.5	838.0	2.9	79.0
Environmental Protection Agency	627.0	283.8	0.0	45.3
Department of Transportation	622.0	192.3	24.8	34.9
Department of the Interior	594.1	534.8	0.0	90.0
Department of Veterans Affairs	363.7	363.7	0.0	100.0
Department of Education	304.5	14.4	0.0	4.7
International Development Cooperation Agency	281.0	27.5	0.0	9.8
Department of Labor	176.8	154.9	0.0	87.6
Department of Justice	117.6	43.2	3.4	39.6
Smithsonian Institution	115.0	115.0	0.0	100.0
Department of the Treasury	80.4	64.4	0.0	80.1
Nuclear Regulatory Commission	68.0	18.7	36.1	80.6
Department of Housing and Urban Development	47.7	23.6	0.0	49.5
Social Security Administration	45.5	4.4	0.0	9.7
Library of Congress	3.5	2.5	0.0	71.4
Department of State	2.5	0.6	0.0	24.0
Federal Communications Commission	2.2	2.2	0.0	100.0
Federal Trade Commission	1.4	1.4	0.0	100.0
Appalachian Regional Commission	0.7	0.0	0.0	0.0
Broadcasting Board of Governors	0.1	0.1	0.0	100.0
National Archives and Records Administration	0.1	0.1	0.0	100.0

FFRDC federally funded research and development center

[a] Intramural activities include actual intramural R&D performance and costs associated with planning and administration of both intramural and extramural programs by Federal personnel.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2001, 2002, and 2003* (Arlington, VA, forthcoming).

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activities—16.7 percent of the $399.2 billion discretionary budget authority in FY 2004—over 90 percent of Federal basic research funding is for nondefense functions, accounting for a large part of the budgets of agencies with nondefense missions such as general science (NSF), health (NIH), and space research and technology [National Aeronautics and Space Administration (NASA)] (table 4-11, appendix table 4-29). Because many different agencies can support R&D programs with the same basic objective, it is useful to aggregate Federal R&D into budget functions to assess broad trends in national R&D priorities.

Space-related R&D as a percentage of total R&D reached a peak of 20.8 percent in 1965, during the height of the nation's efforts to surpass the Soviet Union in space exploration (figure 4-8). In terms of the nation's R&D performance, space-related R&D accounted for an estimated 2.5 percent of total R&D in 2002.[28] The loss of the Space Shuttle Columbia and its crew of seven on February 1, 2003, has resulted in uncertainty as to the future focus and intensity of manned missions in the U.S. space-related R&D effort. In the President's FY 2004 budget, crafted before the disaster, 55.2 percent of NASA's $15.5 billion discretionary budget was reserved for R&D.

The most dramatic change in national R&D priorities over the past 20 years has been the growing importance of health-related R&D. As illustrated in figure 4-9, health-related R&D rose from representing roughly a fourth (27.6 percent) of the Federal nondefense R&D budget allocation in FY 1982 to more than half (54.5 percent) by FY 2003.

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[28] The steep drop in space-related R&D in fiscal year 2000, as depicted in figure 4-9, was the result of the National Aeronautics and Space Administration's (NASA's) reclassifying space station R&D to R&D plant.

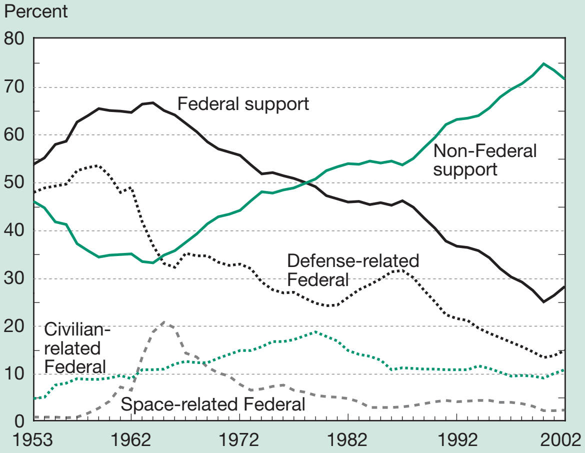
Most of this growth occurred after 1998 when NIH's budget was set on a pace to double by 2003 (Meeks 2002).

In contrast to the steep growth in health-related R&D, the budget allocation for general science R&D has grown relatively little in the past 20 years. In fact, the growth in general science R&D (figure 4-9) is more the result of a reclassification of several DOE programs from energy to general science in FY 1998 than the result of increased budget allocations. The formation of the Department of Homeland Security (DHS) and the coincident reclassification of much of its formerly civilian R&D activities as defense R&D is a more recent example of how R&D budget function classifications can change when the mission or focus of funding agencies changes.

Rationales for Federal Laboratories and FFRDCs

- **Scale.** Some R&D efforts require capital expenditures, facilities, and staffing that exceed the capabilities or resources of private sector research organizations. Termed *big science,* this R&D is often compared to the Manhattan Project of World War II but today spans the spectrum of scientific exploration from medicine (e.g., the National Cancer Institute Frederick Cancer Research and Development Center in Fort Detrick, Maryland) to astronomy (e.g., NSF's National Astronomy and Ionosphere Center in Arecibo, Puerto Rico).
- **Security.** The sensitive nature of some R&D necessitates direct government supervision. Security has historically been a concern of defense-related R&D performed at Department of Defense (DOD) and Department of Energy (DOE) labs and federally funded research and development centers (FFRDCs). However, the growing focus on the threat of bioterrorism highlights that some nondefense R&D, such as that carried out by the Centers for Disease Control and Prevention, also influences national security.
- **Mission and Regulatory Requirements.** Some Federal agencies, such as the Department of Transportation and the Food and Drug Administration, must perform a certain amount of R&D to fulfill their missions. To ensure impartiality and fairness, this R&D is performed in Federal laboratories.
- **Knowledge Management.** For logistical reasons, Federal laboratories and FFRDCs are often tasked with performing long-term or mission-critical R&D. These organizations possess the institutional memory and close connection to the sponsoring agency required by these types of projects. An additional benefit of in-house expertise in R&D sponsoring agencies is the assisting role it plays in the management of extramural R&D programs.

Figure 4-8
Federal and non-Federal share of all R&D: 1953–2002



SOURCE: National Science Foundation, Division of Science Resources Statistics, special tabulations, 2003. See appendix table 4-27.

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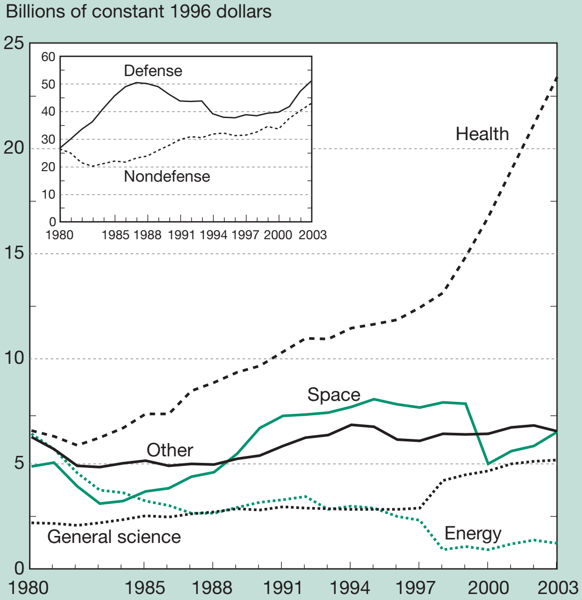
Figure 4-9
Federal R&D budget authority, by budget function: FY 1980–2003



NOTES: "Other" includes all nondefense functions not separately graphed, such as agriculture and transportation. The 1998 increase in general science and decrease in energy and the 2000 decrease in space were the results of reclassification.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal R&D Funding by Budget Function: Fiscal Years 2001–2003,* 2002. See appendix table 4-28.

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Federal R&D for Countering Terrorism

Speaking not long after the terrorist attacks of September 11, 2001, Dr. Rita Colwell, NSF director, remarked, “the research enterprise arches and bends to national needs” (Colwell 2001). Decades of Federal research support developed a knowledge base that was quickly marshaled to address specific scientific and technological issues raised by the attacks and by the threat of future terrorist activity in the United States. Ongoing R&D that had not earlier been categorized under the rubric of homeland security or national defense found immediate applications in the aftermath of September 11. And for those needs that national R&D resources could not meet, new funds, laboratories, and programs were planned.

In fiscal year 2002, the Federal Government appropriated $36.5 billion for combating terrorism, $1.2 billion of which was R&D funding. As a point of reference, the total Federal budget for R&D activities to develop technologies to deter, prevent, or mitigate terrorist acts was less than half this amount ($511 million) in FY 2000. As figure 4-10 indicates, a large portion of the FY 2002 counterterrorism R&D was funded by defense/security agencies, most notably the Defense Advanced Research Projects Agency in DOD. The Department of Health and Human Services (HHS) was the next largest source of funds, with most of its R&D budget accounted for by the National Institutes of Health (NIH). Numerous other agencies, ranging from the Environmental Protection Agency to the Department of Justice (DOJ), supported counterterrorism R&D in FY 2002.

The Federal budget for counterterrorism R&D mushroomed in the President’s FY 2003 budget request to more than $2.9 billion. More than 60 percent of this R&D was requested for HHS, specifically for bioterrorism-related R&D at NIH. Counterterrorism R&D funded by the national security community almost doubled in the FY 2003 budget request, with its emphasis on R&D to support warfighting applications and counterbioterrorism. Ongoing R&D programs at DOE in the fields of genomic sequencing; modeling and simulation; and the detection of nuclear, chemical, and biological agents were also expanded.

Although the FY 2004 budget request did not separate counterterrorism R&D from other R&D programs, the 2.5-fold increase between FY 2002 and FY 2003 appears to have been a one-time event. The FY 2004 budget proposes increases in Federal R&D investment in the priority areas of defense and homeland security, but the most prominent change from the FY 2003 budget is organizational rather than monetary. On January 24, 2003, the Department of Homeland Security (DHS) was officially established and the R&D programs of several agencies were consolidated under its management. The President’s budget request reflects this consolidation and calls for a $1.0 billion R&D budget for the new department. Analysis by the American Association for the Advancement of Science reports this as a 50 percent increase over the disaggregated FY 2003

The Federal S&T Budget

In recent years, alternative concepts have been used to isolate and describe fractions of Federal support that could be associated with scientific achievement and technological progress. In a 1995 report, a National Academy of Sciences (NAS) committee proposed an alternative method of measuring the Federal Government’s S&T investment (NAS 1995). According to the committee members this approach, called the Federal science and technology (FS&T) budget, might provide a better way to track and evaluate trends in public investment in R&D. The FS&T concept differed from Federal funds for research in that it did not include major systems development supported by DOD and DOE, and it contained not only research but also some development and some R&D plant.

Beginning with the FY 2000 budget, the Office of Management and Budget (OMB) has presented its concept for an FS&T budget (figure 4-11). Whereas the NAS FS&T compilation included only R&D, OMB’s FS&T budget was constructed of easily tracked programs and included some non-R&D programs, such as NSF education programs and staff salaries at NIH and NSF.

In the 2004 Budget of the United States, OMB’s FS&T budget is less than half of total Federal spending on R&D because it excludes funding for defense development, testing, and evaluation. It includes nearly all budgeted Federal support for basic research in FY 2004, more than 80 percent of federally supported applied research, and about half of federally supported nondefense development (U.S. OMB 2003b).

As shown in figure 4-12, Federal R&D in the 2004 budget proposal, which includes expenditures on facilities and equipment, would reach a level of $123 billion. Of this amount, $54 billion would be devoted to basic and applied research alone. The FS&T budget would reach $59 billion and would include most of the research budget. However, differences in the definition of research and FS&T imply that not all research would be included in FS&T and vice versa. Moreover, a small proportion (10 percent) of FS&T funds would fall outside the category of Federal R&D spending.

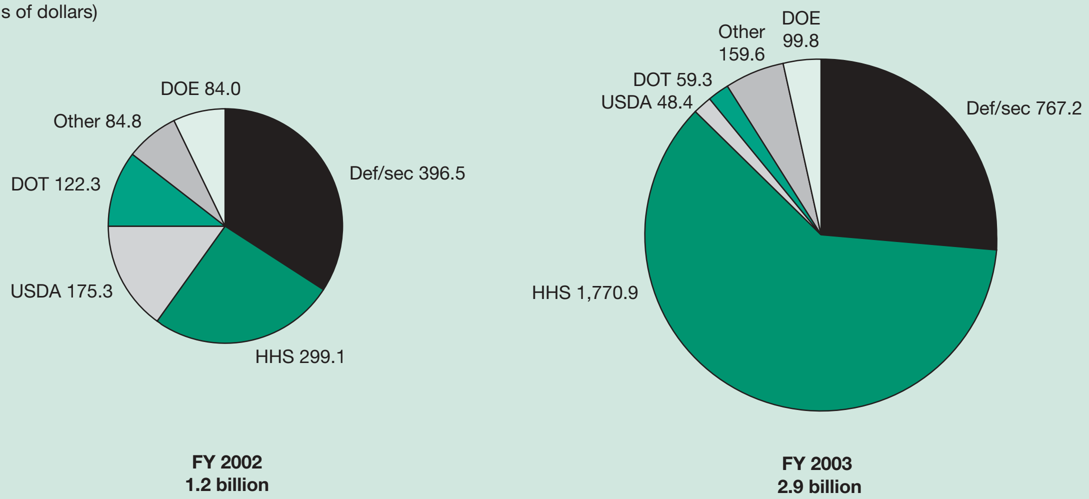
R&D budgets of the agencies, laboratories, and programs that were brought under the aegis of DHS.

DHS is organized into four major directorates: Border and Transportation Security, Emergency Preparedness and Response, S&T, and Information Analysis and Infrastructure Protection. In addition to these directorates, the Secret Service and the Coast Guard report directly to the DHS Secretary, and the Immigration and Naturalization Service adjudications and benefits programs report directly to the Deputy Secretary as the Bureau of Citizenship and Immigration Services.

Figure 4-10

R&D budget for combating terrorism, by agency: FY 2002 and 2003

(Millions of dollars)



Def/sec Defense/security agencies; DOE Department of Energy; DOT Department of Transportation; HHS Department of Health and Human Services; USDA Department of Agriculture

SOURCE: U.S. Office of Management and Budget, *Annual Report to Congress on Combating Terrorism* (Washington, DC, 2002).

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R&D by Federal Agency

The Federal agencies with the largest R&D expenditures vary considerably in terms of how their R&D budgets are spent.[29] Agency-reported data reveal remarkable diversity in terms of the character of the R&D, who performs the R&D, and how R&D is allocated to performers. These differences reflect the diverse missions, histories, and cultures of the agencies.

Department of Defense

According to preliminary data provided by the DOD before budget developments brought about by the war in Iraq, DOD will obligate $45.0 billion, more than any other Federal agency, for R&D support in FY 2003. DOD's support represents 45.6 percent of all Federal R&D obligations (table 4-10). More than 85 percent of these funds ($38.5 billion) will be spent on development, with $33.0 billion slated for major systems development.[30] Industrial firms are expected to perform 65 percent of DOD-funded R&D in FY 2003. These firms will account for an even greater share of development funds (71 percent). DOD's R&D obligations will constitute more than 80 percent of all Federal R&D obligations to industry in FY 2003. Of DOD-funded R&D not performed by industry, government laboratories and FFRDCs are expected to perform 85 percent ($13.3 billion). According to OMB, 63 percent of DOD's basic and applied research funding was allocated using a fully competitive merit review process in 2002.[31]

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[29] The data reported here on expected R&D obligations in FY 2003 were collected before recent budget negotiations and the formation of the Department of Homeland Security. See sidebar "Federal R&D for Countering Terrorism" for data on these recent developments.

[30] The Department of Defense (DOD) reports development obligations in two categories: *advanced technology development,* which is similar in nature to development funded by most other agencies, and *major systems development,* which includes demonstration and validation, engineering and manufacturing development, management and support, and operational systems development for major weapon systems.

[31] In 2002, 69 percent of all Federal research funding was allocated through competitive merit review processes. Twenty percent was merit reviewed, but competition was limited to a select pool of applicants such as Federal labs or FFRDCs. The remaining 11 percent was allocated to specific performers either at the request of Congress or because timeliness or other factors limited the feasibility of competitive selection [U.S. Office of Management and Budget (U.S. OMB) 2003b].

Table 4-11
Budget authority for R&D by Federal agency and character of work, proposed levels: FY 2004

Agency	Discretionary budget authority	R&D total	Basic research	Applied research and development	R&D share of discretionary budget
	Millions of dollars				Percent
All Federal Government	782,219	118,014	26,862	91,152	15.1
Department of Defense	379,898	62,672	1,309	61,363	16.5
Health and Human Services	66,195	28,108	14,804	13,304	42.5
National Institutes of Health	27,742	26,866	14,801	12,065	96.8
National Aeronautics and Space Administration	15,469	8,543	2,535	6,008	55.2
Department of Energy	23,376	7,559	2,593	4,966	32.3
National Science Foundation	5,481	3,690	3,486	204	67.3
Department of Agriculture	19,503	1,803	819	984	9.2
Department of Commerce	5,406	1,006	391	615	18.6
National Oceanic and Atmospheric Administration	3,325	675	312	363	20.3
National Institute for Standards and Technology	498	318	79	239	63.9
Department of the Interior	10,587	633	38	595	6.0
Department of Transportation	13,673	674	37	637	4.9
Environmental Protection Agency	7,627	607	90	517	8.0
Department of Veterans Affairs	28,057	822	495	327	2.9
Department of Education	53,137	275	1	274	0.5
Department of Homeland Security	26,697	836	47	789	3.1
International assistance programs	17,039	306	58	248	1.8
Smithsonian Institution	567	121	121	0	21.3
Tennessee Valley Authority	NA	25	NA	25	NA
Department of Labor	11,535	10	2	8	0.1
Nuclear Regulatory Commission	626	60	NA	60	9.6
Corps of Engineers	4,049	27	3	24	0.7
Department of Housing and Urban Development	31,301	51	NA	51	0.2
Department of Justice	17,697	106	33	73	0.6
Social Security Administration	3,084	30	NA	30	1.0
Postal Service	NA	47	NA	47	NA
Department of the Treasury	11,397	3	NA	3	0.0

NA not available

NOTE: Details will not add to totals for discretionary budget authority because only R&D funding agencies are listed.

SOURCE: Intersociety Working Group, *AAAS Report XXVIII: Research and Development FY 2004* (Washington, DC, 2003); and U.S. Office of Management and Budget, *Budget of the United States Government, Fiscal Year 2004* (Washington, DC, 2003).

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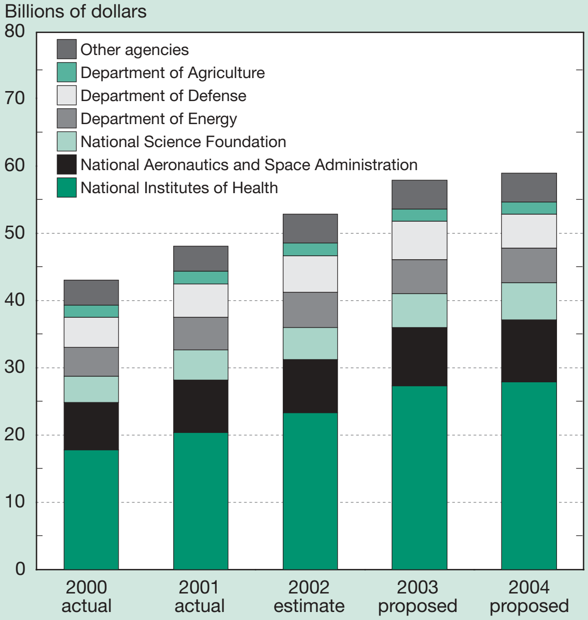
Department of Health and Human Services

HHS, the primary source of Federal health-related R&D funding (largely through NIH), will obligate the second largest amount for R&D in FY 2003 at $27.6 billion, most of which ($14.5 billion) will be for basic research. In FY 2003, HHS is expected to provide universities and colleges, the primary recipients of HHS funding, with $15.5 billion, or 67.4 percent of all Federal R&D funds obligated to universities and colleges (table 4-12). HHS will provide 75.6 percent ($4.7 billion) of all Federal R&D funds obligated to nonprofit institutions, with most of these funds going to such large research hospitals as Massachusetts General Hospital and the Dana-Farber Cancer Institute (NSF/SRS 2002). In 2002, fully competitive merit review processes were used to allocate 81 percent of HHS's basic and applied research funding.

National Aeronautics and Space Administration

The third largest agency in terms of R&D support is NASA, with R&D obligations expected to total $8.6 billion in FY 2003; 28.6 percent ($2.5 billion) will be earmarked for basic research. Although not defense related, much of the development work sponsored by NASA relies on industrial performers similar to those funded by DOD. NASA is the second largest source of industrial R&D funds, an expected $3.6 billion in FY 2003. Roughly 82 percent of NASA-funded R&D is performed either by industrial firms or in Federal labs or FFRDCs. Academic and nonprofit institutions perform the remainder. In 2002, 85 percent of NASA's basic and applied research funding was allocated using a fully competitive merit review process.

Figure 4-11
Federal science and technology budget, by agency: FY 2000–2004



SOURCES: U.S. Office of Management and Budget, *Analytical Perspectives, Budget of the United States Government, Fiscal Year 2004* (Washington, DC, 2003); and U.S. Office of Management and Budget, *Analytical Perspectives, Budget of the United States Government, Fiscal Year 2003* (Washington, DC, 2002).

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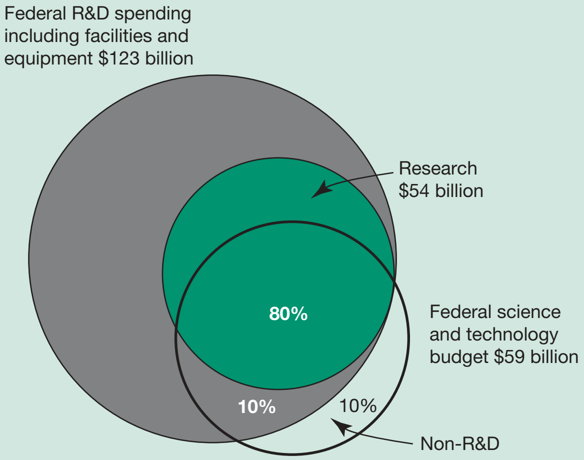
Figure 4-12
Funding concepts in FY 2004 budget proposal



NOTE: Percents represent shares of the Federal science and technology budget rounded to the nearest 10 percent.

SOURCE: U.S. Office of Management and Budget, *Analytical Perspectives, Budget of the United States Government: Fiscal Year 2004* (Washington, DC, 2003).

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Department of Energy

Of the large R&D-funding agencies, DOE relies the most on the R&D capabilities of FFRDCs, obligating 61.1 percent of its estimated $7.5 billion in FY 2003 R&D funding to FFRDCs. DOE is the largest funding source of the 36 FFRDCs, accounting for 61.2 percent of all Federal R&D obligations to FFRDCs in FY 2003. DOE's high reliance on its intramural laboratories and FFRDCs explains why the share of its research funding that was allocated using a fully competitive merit review process in 2002 was relatively low at 23 percent.

National Science Foundation

NSF is the Federal Government's primary source of funding for general S&E R&D and is expected to fund $3.4 billion in R&D in FY 2003. Of these funds, 94.2 percent are for basic research. NSF is the second largest Federal source of R&D funds to universities and colleges and is expected to provide $2.8 billion to academic researchers in FY 2003. In 2002, 95 percent of NSF's basic and applied research funding was allocated using a fully competitive merit review process.

Other Agencies

DOD, HHS, NASA, DOE, and NSF are expected to account for 93.4 percent of all Federal R&D obligations in FY 2003, with 93.9 percent for basic research, 85.6 percent for applied research, and 97.8 percent for development. Unlike those Federal agencies, the Department of Agriculture (USDA), DOC, and Department of the Interior (DOI) obligate most of their R&D funds to mission-oriented R&D conducted in their own laboratories, which are run by the Agricultural Research Service, the National Institute for Standards and Technology (NIST), and the U.S. Geological Survey, respectively.

Federal R&D Funding by Performer and Field of Science or Engineering

Federal Funding to Academia

The Federal Government has long provided the largest share of R&D funds used by universities and colleges. In the early 1980s, Federal funds accounted for roughly two-thirds of the academic total. That share dropped to 57.7 percent in 2000 but is expected to rise to 58.5 percent in 2002. Although this share of funding has not changed much in recent years, the actual amount of funding in real terms increased on average 5.1 percent per year between 1985 and 1994, 3.4 percent per year between 1994 and 2000, and 7.3 percent per year between 2000 and 2002. For more information on academic R&D, see chapter 5.

Federal Funding to Industry

The greatest fluctuation in Federal support as reported by R&D performers occurred in obligations to industry, ranging from a low of $10.4 billion (constant 1996 dollars) in 1955 (when the NSF time series began) to a high of $37.1

Table 4-12
Estimated Federal R&D obligations, by performing sector and agency funding source: FY 2003

Character of work and performer	Total obligations (millions of dollars)	Primary funding source		Secondary funding source	
		Agency	Percent	Agency	Percent
All R&D	98,608	DOD	46	HHS	28
Federal intramural laboratories	24,558	DOD	51	HHS	21
Industrial firms	36,411	DOD	81	NASA	10
Industry-administered FFRDCs	1,478	DOE	71	HHS	19
Universities and colleges	23,055	HHS	67	NSF	12
Universities and colleges FFRDCs	4,835	DOE	58	NASA	29
Other nonprofit organizations	6,261	HHS	76	NASA	9
Nonprofit-administered FFRDCs	1,222	DOE	60	DOD	33
Basic research	25,977	HHS	56	NSF	12
Federal intramural laboratories	4,411	HHS	43	USDA	15
Industrial firms	1,446	NASA	38	HHS	31
Industry-administered FFRDCs	220	HHS	76	DOE	24
Universities and colleges	14,024	HHS	65	NSF	19
Universities and colleges FFRDCs	1,984	DOE	60	NASA	27
Other nonprofit organizations	3,153	HHS	85	NSF	7
Nonprofit-administered FFRDCs	571	DOE	93	HHS	5
Applied research	27,400	HHS	45	DOD	17
Federal intramural laboratories	8,799	HHS	37	DOD	22
Industrial firms	5,119	DOD	40	NASA	38
Industry-administered FFRDCs	762	DOE	80	HHS	15
Universities and colleges	8,205	HHS	78	DOD	6
Universities and colleges FFRDCs	1,494	DOE	87	NASA	5
Other nonprofit organizations	2,598	HHS	75	NASA	8
Nonprofit-administered FFRDCs	171	DOE	57	DOD	22
Development	45,231	DOD	85	NASA	6
Federal intramural laboratories	11,347	DOD	86	NASA	6
Industrial firms	29,846	DOD	91	NASA	3
Industry-administered FFRDCs	495	DOE	78	DOD	22
Universities and colleges	826	DOD	60	NASA	16
Universities and colleges FFRDCs	1,356	NASA	58	DOE	26
Other nonprofit organizations	510	NASA	35	DOD	25
Nonprofit-administered FFRDCs	481	DOD	76	DOE	23

FFRDC federally funded research and development center; DOD Department of Defense; HHS Department of Health and Human Services; NASA National Aeronautics and Space Administration; DOE Department of Energy; NSF National Science Foundation; USDA Department of Agriculture

NOTE: Subtotals by performer do not add to total because state and local governments and foreign performers of R&D are not detailed.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2001, 2002, and 2003* (Arlington, VA, forthcoming).

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billion in 1987 (figure 4-13). Between 1998 and 2002 Federal funds for industrial R&D activities declined an annual average of 7.8 percent in real terms. Overall the Federal share of industry's performance has been steadily declining since its peak of 56.7 percent in 1959. Beginning in 1989, the amount of federally funded R&D reported by industry began to diverge from the amount reported by the Federal Government. For details on this discrepancy, see sidebar, "Tracking R&D: Gap Between Performer- and Source-Reported Expenditures.''

The industries that report the greatest amount of Federal R&D funding include the computer and electronic products industry; the professional, scientific, and technical services industry; and the aerospace industry. Companies in these three industries accounted for 87 percent of all federally funded industrial R&D reported in 2001. In contrast, this same group accounted for only 37 percent of all company-financed R&D in 2001. Approximately half of the $7.9 billion of R&D performed by companies classified in the aerospace industry came from Federal sources in 2001. In comparison, companies classified in the pharmaceuticals and medicines industry reported no federally funded research in 2001.

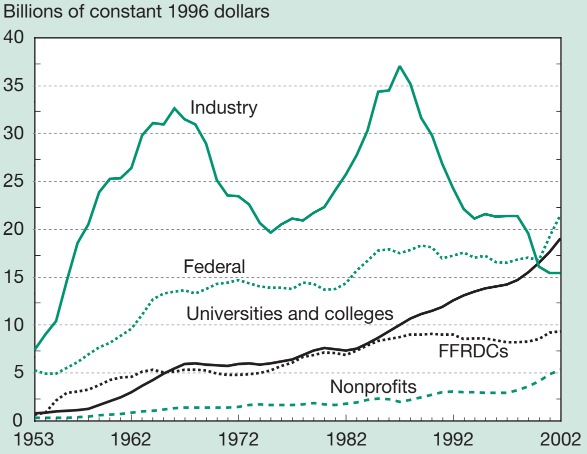
Federal Research Funding by Field

According to preliminary estimates, Federal obligations for research alone (excluding development) will total $53.4 billion in FY 2003. Life sciences will receive the largest portion of this funding (53.7 percent, or $28.7 billion), most of which will be provided by HHS, followed by engineering (17.2 percent), physical sciences (9.7 percent), environmental sciences (7.3 percent), and mathematics and computer sciences (5.4 percent) (figure 4-14). Social sciences, psychology, and all other sciences will account for another 2.0, 1.8, and 3.0 percent, respectively.

HHS, primarily through NIH, will provide the largest share (50.2 percent) of all Federal research obligations in FY 2003. The next largest contributor will be DOD (12.2 percent), providing substantial funding for research in engineering ($3.3 billion) and in mathematics and computer sciences ($1.1 billion). NASA will provide 10.8 percent, primarily in the fields of engineering, environmental sciences, and physical sciences. DOE will provide 10.1 percent, primarily in the fields of physical sciences and engineering. NSF will provide 6.4 percent, contributing between $0.5 and $0.6 billion to each of the following fields: physical sciences, mathematics and computer sciences, engineering, environmental sciences, and life sciences.

Federal obligations for research have grown at different rates for different S&E fields, reflecting changes in perceived public needs in those fields, changes in the national

Figure 4-13
Federal R&D support, by performing sector: 1953–2002



FFRDC federally funded research and development center

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* annual series. See appendix table 4-6.

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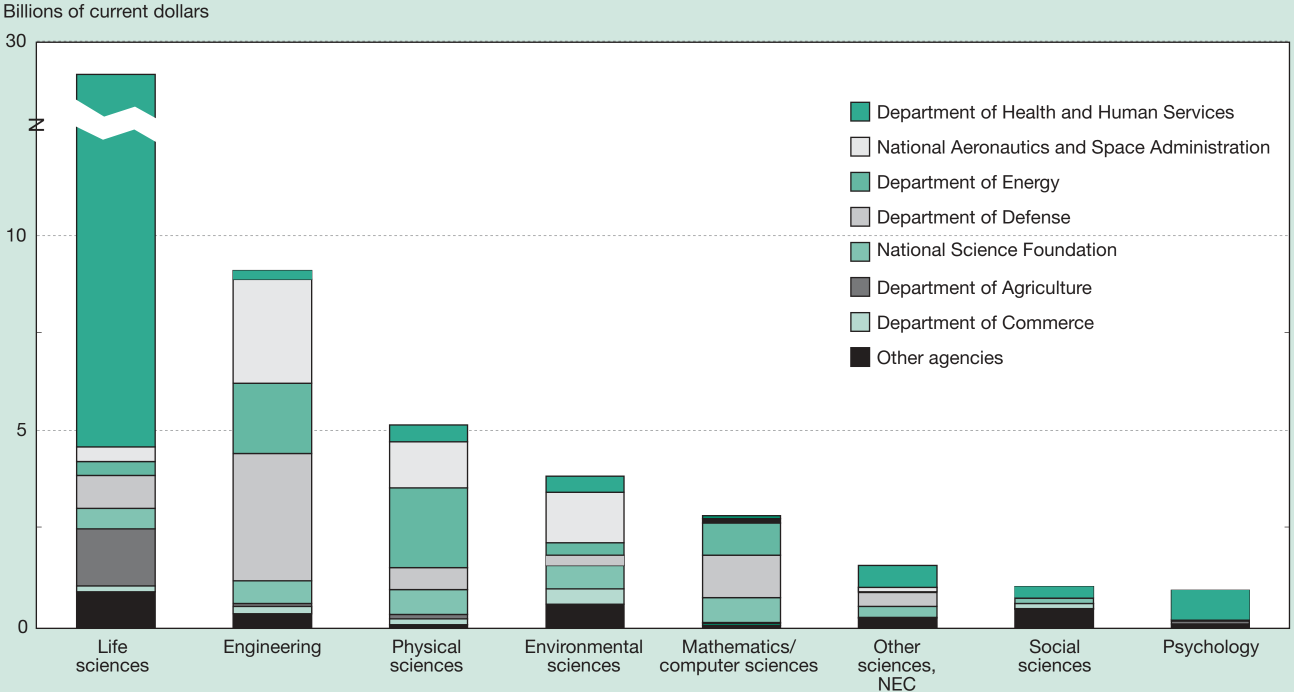
Figure 4-14
Federal obligations for research, by agency and major S&E field: FY 2003



NEC not elsewhere classified

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2001, 2002, and 2003,* forthcoming. See appendix table 4-33.

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Tracking R&D: Gap Between Performer- and Source-Reported Expenditures

In many Organisation for Economic Co-operation and Development (OECD) countries, including the United States, total government R&D support figures reported by government agencies differ substantially from those reported by performers of R&D work. Consistent with international guidance and standards, most countries' national R&D expenditure totals and time series are based primarily on data reported by performers (OECD 2002f). This convention is preferred because performers are in the best position to indicate how much they spent conducting R&D in a given year and to identify the source of their funds. Although funding and performing series may be expected to differ for many reasons such as different bases used for reporting government obligations (fiscal year) and performance expenditures (calendar year), the gap between the two R&D series has widened during the past several years.

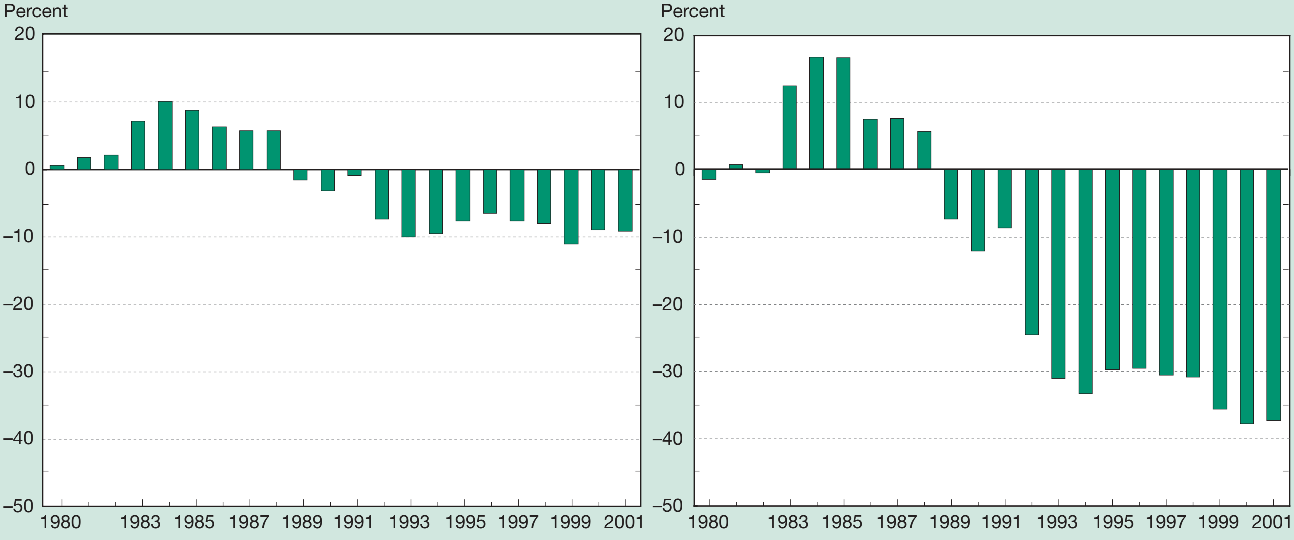
For the United States the reporting gap has become particularly acute over the past several years. In the mid-1980s, performer-reported Federal R&D exceeded Federal reports by $3 to $4 billion annually (5–10 percent of the government total). This pattern reversed itself toward the end of the decade; in 1989 the government-reported R&D total exceeded performer reports by $1 billion. The gap subsequently grew to about $7 billion by 2001. In other words, approximately 9 percent of the government total in 2001 was unaccounted for in performer surveys (figure 4-15). The difference in Federal R&D totals was primarily in DOD development funding of industry. For 2001 Federal agencies reported $27.0 billion in total R&D obligations to industrial performers, compared with $16.9 billion in Federal funding reported by industrial performers. (DOD reported industrial R&D funding of $21.4 billion, whereas industry reported using $10.0 billion of DOD's R&D funds.) Overall, industrywide estimates equal a 37 percent paper "loss" of federally reported 2001 R&D support (figure 4-15).

NSF has sponsored ongoing research and investigations into the possible causes for the data gap. Past studies have focused on the following aspects of the phenomenon:

- The relative prominence of similar divergences in the series in countries with large defense R&D expenditures [National Science Board (NSB) 1998]
- Industry interpretations and financial treatment of Federal (particularly defense-related) R&D contracts (NSB 2000)
- Federal agency R&D data collection and reporting procedures (NSB 2002)

Each investigation resulted in useful insights into the issue, but a conclusive explanation has yet to be identified. According to a recent U.S. General Accounting Office (2001b, p. 2) investigation, "Because the gap is the result of comparing two dissimilar types of financial data [Federal obligations and performer expenditures], it does not necessarily reflect poor quality data, nor does it reflect whether performers are receiving or spending all the Federal R&D funds obligated to them. Thus, even if the data collection and reporting issues were addressed, a gap would still exist."

Figure 4-15
Difference in U.S. performer-reported and agency-reported Federal R&D: 1980–2001



All performers **Industrial performers**

NOTE: Difference is defined as percentage of federally reported R&D, with a positive difference indicating that performer-reported R&D exceeds agency-reported R&D.

SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), special tabulations, 2003; and NSF/SRS, *Federal Funds for Research and Development: Fiscal Years 2001, 2002, and 2003,* forthcoming. See appendix table 4-31.

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resources (e.g., scientists, equipment, and facilities) that have been built up in those fields over time, as well as differences in scientific opportunities across fields (appendix table 4-34). Based on preliminary estimates for FY 2003, the major field of mathematics and computer sciences has experienced the highest rate of growth in Federal obligations for research, which was 7.8 percent per year in real terms between 1982 and 2003. Life sciences had the second highest rate (6.2 percent), followed by psychology (4.6 percent); environmental sciences (3.3 percent); social sciences, including anthropology, economics, political sciences, sociology, and other areas (2.3 percent); engineering (2.2 percent); and physical sciences (1.0 percent).

The trends in Federal support for these broad fields of research, however, may not reflect trends for the smaller fields that they contain. For example, within the broad field of mathematics and computer sciences, Federal support for research in mathematics grew 3.3 percent per year in real terms between FY 1982 and FY 2001, whereas support for research in computer sciences grew 10.9 percent.[32] Within life sciences during the same period, support for biological and agricultural research grew 6.0 percent, compared with research support for medical sciences, which grew 4.3 percent. Within the physical sciences, support for astronomy grew 2.7 percent, whereas support for physics declined 0.5 percent.

Caution should be employed when examining these trends in Federal support for detailed S&E fields because Federal agencies classify a significant amount of R&D only by major S&E field such as life sciences, physical sciences, or social sciences. In FY 2001, for example, 16.6 percent of the Federal research obligations classified by major S&E field were not subdivided into detailed fields. This was less pronounced in physical sciences and in mathematics and computer sciences, in which all but 7.6 percent of the research dollars were subdivided. It was most pronounced in engineering and social sciences, in which 27.3 and 63.9 percent, respectively, of the research obligations were not subdivided into detailed fields.

Federal R&D Tax Credit

The traditional justification for tax incentives for research activities is that results from these activities, especially more basic or long-term research, are often hard to capture privately because others might benefit directly or indirectly from them. Therefore, businesses might engage in levels of research below those that would be beneficial to the nation as a whole. In this regard, direct funding and tax incentives are complementary fiscal tools. Tax incentives are thought to stimulate R&D activity generally across industries and technologies (Tassey 1996), whereas direct funding through government agencies (as well as certain industry-relevant academic research) stimulates R&D in targeted fields (e.g., health, energy, or defense) or by certain performers [e.g., Small Business Innovation Research Program (SBIR)].[33]

The Federal research and experimentation (R&E) tax credit was first established on a temporary basis in 1981 and has been renewed several times since.[34] It was last reinstated by the Tax Relief Extension Act of 1999 through June 30, 2004. The Bush administration and several congressional bills pending, as of this writing, propose to make the R&E credit permanent (Knezo 2002).

Several studies based on U.S. data from the late 1990s have concluded that a dollar in tax credit likely stimulates, on average, a dollar of additional R&D on a long-term basis, as well as smaller short-term effects (Bloom, Griffith, and Van Reenen 2002; and Hall and Van Reenen 2000). However, the studies caution that administrative costs are often ignored in most empirical studies. In addition, for a more complete assessment of this policy instrument, interactions with other components of corporate taxes and tradeoffs with other policies need to be integrated into purely cost-benefit analyses.

Structure of the Credit and Tax Data

A regular credit is provided for 20 percent of qualified research above a base amount based on the ratio of research expenses to gross receipts for 1984–88. Startup or younger companies follow different formulas. An alternative R&E credit is available for corporate fiscal years that began after June 30, 1996.[35] Both the regular and the alternative R&E credits include provisions for basic research payments paid to qualified universities or scientific research organizations above a certain base-period amount.

In 1999 (the latest year for which data are available), approximately 10,000 companies claimed $5.281 billion in R&E credits, about the same level as in 1998 (table 4-13). However, not all R&E claims are allowed because there is a limitation on the reduction of a company’s total tax liability. In 1999, 267 companies claimed $540 million for basic research, about 10 percent of the total R&E credit. The 1999 basic research credits were 36 percent larger than those in 1998, but the number of claims declined by half.

Federal Budget Impact

R&E credits are tax expenditures or government revenue losses because of preferential provisions. Tax expenditures from corporate income taxes relate mostly to cost recovery for certain investments, including research activities. *Outlay-equivalent* is one of three accounting methods used to

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[32] For these subfields, the latest available data are for FY 2001.

[33] The SBIR program is discussed later in this chapter in “Small Business S&T Programs.”

[34] This section covers the R&D tax credit in the United States. For R&D tax policies abroad, see the discussion of R&D promotion policies in “International R&D by Performer, Source, and Character of Work.”

[35] The alternative credit is a lower rate that applies to all research expenses exceeding 1 percent of revenues or sales. The rates were raised by the 1999 Tax Relief Act to 2.65–3.75 percent. Companies may select only one of these two credit modes on a permanent basis unless the Internal Revenue Service authorizes a change. The 1999 act also extended the research credit to include R&D conducted in Puerto Rico and other U.S. possessions.

Table 4-13
Research and experimentation tax credit claims: 1990–99

Year	Billions of current dollars	Number of tax returns
1990	1.547	8,699
1991	1.585	9,001
1992	1.515	7,750
1993	1.857	9,933
1994	2.423	9,150
1995	1.422	7,877
1996	2.134	9,709
1997	4.398	10,668
1998	5.208	9,849
1999	5.281	10,020

SOURCE: U.S. Department of the Treasury, Internal Revenue Service, Statistics of Income, unpublished tabulations.

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estimate these tax expenditures.[36] This method converts R&E credits into data comparable to Federal R&D outlays.

According to this measure, tax credit claims in 1999 were equivalent to outlays of $2.625 billion, or 3.5 percent of direct Federal R&D outlays in 1999 (U.S. OMB 2000) (appendix table 4-35). Although R&E claims data for tax year 2000 are not available, the credit generated an estimated outlay equivalent of $2.510 billion, or 3.4 percent of Federal R&D outlays in 2000 (U.S. OMB 2001).

Technology Linkages: Contract R&D, Federal Technology Transfer, and R&D Collaboration

In recent decades, the speed, complexity, and multidisciplinary nature of scientific research, coupled with the increased relevance of science for industrial technology development and the demands of a globally competitive environment, have increased the importance of technology linkages for innovation and long-term competitiveness (Branscomb and Florida 1998). Although external technology sources, including university research, have long played a key role in U.S. industry innovation and competitiveness (Mowery 1983; and Rosenberg and Nelson 1994), the current environment has encouraged an innovation system increasingly characterized by networking and feedback among R&D performers, technology users, and their suppliers and across industries and national boundaries (Coombs and Georghiou 2002; and Vonortas 1997). Several Federal S&T policies have also facilitated private R&D collaboration and Federal technology transfer, as discussed in more detail throughout this section. (See sidebar, "Major Federal Legislation Related to Cooperative R&D and Technology Transfer.")

Available indicators reveal increased cross-sector linkages over the 1990s. Manufacturing companies increased contract R&D expenditures at a 4.8 average annual percent rate, in real or inflation-adjusted terms, between 1993 and 2001, a full annual percentage point higher than the growth of in-house company-funded R&D expenditures over the same period. Federal agencies reporting technology transfer data to DOC increased their invention disclosures, patent activity, and licensing in FY 2001, reflecting their unique capabilities in terms of multidisciplinary R&D and specialized facilities. Patents issued to these Federal agencies topped 1,600 in FY 2001, up 15.6 percent from FY 2000.

The other major intersectoral activity involves cooperative R&D. U.S. Federal agencies participated in more than 3,600 Cooperative R&D Agreements (CRADAs) with industrial and nonprofit organizations in FY 2001, although new CRADAs have been stable at about 1,000 annually since FY 1997. In addition, between 1991 and 2001, U.S. companies participated in more than 4,600 research and technology alliances worldwide, or about 80 percent of all such alliances involving U.S., European, Japanese, and emerging-market companies. Activity was particularly strong in IT and biotechnology.

Outsourcing and collaboration aimed at the acquisition or development of technologies may reduce costs, expedite projects, or complement internal R&D capabilities (Howells and James 2001). Activities linking business, academic, and government laboratories may take place in special-purpose settings such as science parks. (See sidebar, "U.S. Science Parks.") The following sections discuss data on contract R&D, Federal technology transfer (e.g., patent licensing), and R&D alliances involving private companies, universities, and government laboratories.

Contract R&D

Many companies have increasingly come to rely on other firms for a portion of their R&D needs. In fact, the growth rate of *contract R&D*, defined as company-funded R&D performed externally, exceeded that of company-funded R&D performed in-house in recent years, even after a decline in contract R&D expenditures in 2001. In 2001, more than 1,300 manufacturing companies (8 percent of all R&D-performing manufacturing companies in the United States) reported $4.0 billion ($3.6 billion in constant or inflation-adjusted dollars) in expenditures for contract R&D performed in the United States, compared with $4.8 billion ($4.5 billion in constant dollars) in 2000, a decline of 17.5 percent, according to NSF's Survey of Industrial Research and Development.[37] In contrast, their in-house company-funded R&D declined only 1.4 percent between 2000 and 2001. Over a longer time span, however, manufacturing companies increased contract R&D expenditures at a 4.8 average annual percentage rate in real, or inflation-adjusted, terms, a full annual percentage point higher than the growth

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[36] The other two methods are *revenue loss* and *present value.* For a comparison of these methods, see U.S. OMB (2001).

[37] National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2003. Available at http://www.nsf.gov/sbe/srs/indus/start.htm.

Major Federal Legislation Related to Cooperative R&D and Technology Transfer

- **Stevenson-Wydler Technology Innovation Act (1980)**—required Federal laboratories to facilitate the transfer of federally owned and originated technology to state and local governments and the private sector.
- **Bayh-Dole University and Small Business Patent Act (1980)**—permitted government grantees and contractors to retain title to federally funded inventions and encouraged universities to license inventions to industry. The act is designed to foster interactions between academia and the business community.
- **Small Business Innovation Development Act (1982)**—established the Small Business Innovation Research (SBIR) program within the major Federal R&D agencies to increase government funding of research that has commercialization potential within small high-technology companies.
- **National Cooperative Research Act (1984)**—encouraged U.S. firms to collaborate on generic, precompetitive research by establishing a rule of reason for evaluating the antitrust implications of research joint ventures. The act was amended in 1993 by the National Cooperative Research and Production Act (NCRPA), which let companies collaborate on production activities as well as research activities.
- **Federal Technology Transfer Act (1986)**—amended the Stevenson-Wydler Technology Innovation Act to authorize cooperative research and development agreements (CRADAs) between Federal laboratories and other entities, including state agencies.
- **Omnibus Trade and Competitiveness Act (1988)**—established the Competitiveness Policy Council to develop recommendations for national strategies and specific policies to enhance industrial competitiveness. The act created the Advanced Technology Program and the Manufacturing Technology Centers within the National Institute for Standards and Technology to help U.S. companies become more competitive.
- **National Competitiveness Technology Transfer Act (1989)**—amended the Stevenson-Wydler Act to allow government-owned, contractor-operated laboratories to enter into CRADAs.
- **National Cooperative Research and Production Act (1993)**—relaxed restrictions on cooperative production activities, enabling research joint venture participants to work together in the application of technologies they jointly acquire.
- **Technology Transfer Commercialization Act (2000)**—amended the Stevenson-Wydler Act and the Bayh-Dole Act to improve the ability of government agencies to monitor and license federally owned inventions.

of in-house company-funded R&D expenditures between 1993 and 2001, reflecting the importance of outside sources of technology for a number of corporate technology objectives (appendix table 4-36).

In the manufacturing industry the overall ratio of expenditures for contract R&D to expenditures for R&D performed in-house increased from 3.3 percent in 1993 to a peak of 4.7 percent in the mid-1990s, then moderated somewhat to 3.6 percent in 2001 (figure 4-16). In 2001 the proportion was higher for chemicals manufacturing at 11.7 percent (and pharmaceuticals manufacturing at 18.7 percent) (appendix table 4-37). Within nonmanufacturing industries, the contract R&D ratios for the information sector and the professional, scientific, and technical services sector were notable at 3.3 and 7.4 percent, respectively. Within the latter industry, R&D services contracted out $1.3 billion in R&D activities in 2001, which is 12.0 percent of its $10.9 billion in internal company-funded R&D expenditures.

Of the manufacturing companies reporting contract R&D in the NSF survey in 2001, 132 companies (9.7 percent) identified $2.17 billion in R&D expenditures in terms of their R&D contractors being for-profit companies, universities and colleges, or other nonprofit organizations.[38] The highest proportion of these identified contract R&D expenditures, 92.0 percent, funded other companies, 5.9 percent funded universities and colleges, and 2.2 percent funded other nonprofit institutions. For chemical companies, the distribution of contract R&D expenditures among their R&D contractors was similar (83, 12, and 5 percent, respectively). However, among companies in the scientific R&D services sector, the share of identified contract R&D expenditures performed by universities and colleges was much higher, 35.4 percent, although still second to the 49.7 percent performed by other for-profit companies.[39] The relatively higher reliance of U.S. R&D services companies on universities and colleges as R&D subcontractors may be related to the broader set of technologies in which these companies work, complementing their internal capabilities with the wide array of scientific capabilities of universities.

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[38] National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2003. Available at http://www.nsf.gov/sbe/srs/indus/start.htm.

[39] Disclosure limitations preclude further industry-level analyses.

U.S. Science Parks

Science, or research, parks are real estate developments involving technology transfer activities. Many science parks are affiliated with or supported by universities or government agencies, and some are also business incubators, offering assistance to new technology-based companies.* Science parks affiliated with universities have been in place since the 1950s in the United States. Some of the oldest and largest parks include Stanford Research Park (Stanford, CA), established in 1951, and Research Triangle Park (Research Triangle, NC), established in 1959 (Link and Link 2003). However, the increased research and patenting output from academic R&D since the 1980s have intensified the role of industry-university linkages as avenues for knowledge diffusion and broad economic benefits.† Similarly, selected Federal laboratories house or sponsor science parks and business incubators (NRC 2003).

In an exploratory study involving 50 U.S. science parks, Link and Link (2003) analyzed parks with and without university affiliation. University-related parks were classified, for example, in terms of the presence or absence of tenant criteria regarding R&D intensity or commitment to interacting with students and faculty. Forty of the examined science parks were affiliated with a university and about a third of the parks were also business incubators. Tenant criteria of university-related parks were found to affect positively their growth in terms of participating companies and number of employees. However, the 10 science parks in their sample that had no university linkages were larger parks.

A workshop on science parks indicators sponsored by NSF in late 2002 concluded that science parks are "an important mechanism for the transfer of academic research findings, a source of knowledge spillovers, and a catalyst for national and regional economic growth" (Link 2003, p. 1). Participants also noted the need for metrics on the profile and performance of these parks. NSF is considering recommendations from workshop participants while continuing to fund a number of research projects on the topic, including exploring existing data on domestic R&D alliances in terms of university and science park affiliation.

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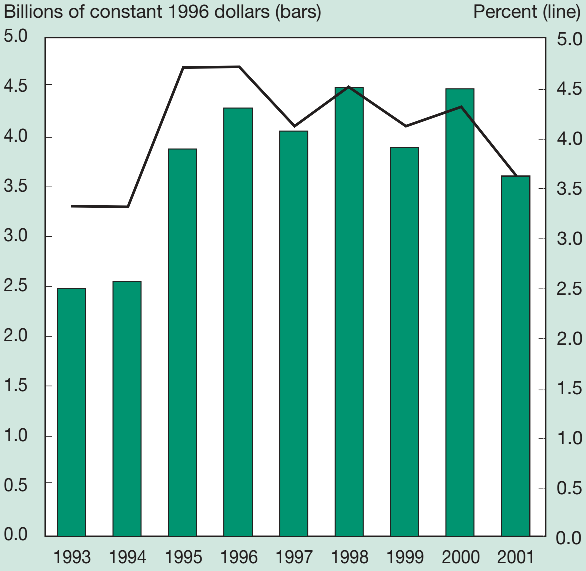
*See chapter 6.
†See chapter 5.

Figure 4-16
Manufacturing contract R&D expenditures in United States and ratio of contract R&D expenditures to company-funded R&D performed within companies: 1993–2001



SOURCE: National Science Foundation, Survey of Industrial Research and Development, annual series. See appendix table 4-36.

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Federal S&T Programs and Technology Transfer

Concerns over U.S. industrial strength and global competitiveness in the late 1970s and early 1980s led to a series of legislative changes that collectively created an environment conducive to industry-government collaboration in technology development (Link 1999). This section discusses technology transfer and collaborative activities involving Federal laboratories. *Technology transfer* can be defined as the exchange or sharing of technical knowledge, skills, processes, or products across different organizations.[40] Technology transfer activities involving Federal laboratories include patenting, licensing, joint R&D, user-facility agreements, and technical assistance.

Technology transfer functions performed by certain Federal laboratories, namely, intramural or government-owned–government-operated laboratories, such as NIH or the Agricultural Research Service, were established by the Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480). Later in the decade, the Federal Technology Transfer Act of 1986 authorized intramural labo-

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[40] This section describes technology transfer activities associated with R&D performed in federally owned laboratories (hereafter, *Federal laboratories*), whether run by Federal agencies themselves or by contractors. It does not include technology transfer activities associated with federally sponsored R&D performed by *independent* extramural entities (for example, companies and universities engaged in patenting resulting from federally sponsored R&D).

ratories to enter into CRADAs[41] with industrial partners, universities, and other organizations, whereas the FY 1990 DOD Authorization Act (Public Law 101-189) extended this authority to government-owned–contractor-operated laboratories, including government-owned FFRDCs[42] (Schacht 2000). In CRADAs, Federal laboratories may share or provide personnel, services, equipment, or facilities (but not funds) with or to a private organization as part of a joint R&D project with the potential to promote industrial innovation consistent with the agency's mission. Private partners may retain ownership rights or acquire exclusive licensing rights for the developed technologies. More recently, the Technology Transfer Commercialization Act of 2000 (Public Law 106-404) enhanced the ability of Federal agencies to license (and monitor) federally owned inventions.

R&D Funding Trends in Federal Laboratories

The share of Federal R&D obligations devoted to intramural laboratories and FFRDCs declined from 39 percent in the early 1980s to the low 30s in the late 1990s (NSF forthcoming). Still, the role of Federal laboratories, either as a source of technology to be commercialized by private parties or as a research partner, is considerable. Federal laboratories offer industrial and nonprofit researchers unique capabilities, such as the ability to perform interdisciplinary research and to use expensive, specialized equipment (Bozeman 2000).

In FY 2001 the Federal Government obligated $27.3 billion, or 34 percent of $79.9 billion in Federal funds earmarked for R&D, to Federal laboratories (table 4-14), compared with $52.6 billion (66 percent of total) in R&D funding obligated to extramural performers, such as companies and universities (NSF forthcoming). Within individual agencies, the share devoted to government laboratories is largest for DOE (71.7 percent) and smallest for HHS (20.3 percent; 19.6 percent for its NIH component). Agencies with large amounts or relatively large proportions of their R&D obligations devoted to intramural and FFRDC performers have more internal outputs available for patenting and licensing than agencies that channel their R&D funds to extramural performers.

Federal agencies devoted a higher share of their funds for Federal laboratories to applied research and development than to basic research. Of the 34 percent devoted to Federal laboratories in FY 2001, less than a fourth went to basic research. Individual Federal agencies, however, varied considerably in the proportion of funds they devoted to basic research in their laboratories: 52.4 percent of HHS laboratory R&D funding (59.5 percent for its NIH component), followed by USDA (49.0 percent) and DOE (35.0 percent). DOD devoted only 5.3 percent to basic research in its laboratories. This profile of character of work at Federal laboratories, together with the various S&T emphases of these agencies, suggests that industrial partners are potentially able to use Federal facilities as a source for a variety of research outputs.

Table 4-14
Federal obligations for R&D, by selected agency, performer, and basic research component: FY 2001

Agency	Federal obligations for R&D	Intramural and FFRDCs R&D	Intramural and FFRDCs basic research	Intramural and FFRDCs R&D share of Federal R&D obligations	Intramural and FFRDCs basic research share of Intramural and FFRDCs R&D
	Millions of current dollars			Percent	
All Federal agencies	79,933.2	27,293.2	6,671.6	34.1	24.4
Top five agencies	72,746.6	24,721.4	6,056.9	34.0	24.5
DOD	35,422.6	11,073.6	587.3	31.3	5.3
DOE	6,668.0	4,779.0	1,670.5	71.7	35.0
HHS	21,341.9	4,340.5	2,275.0	20.3	52.4
NASA	7,355.0	3,267.4	906.5	44.4	27.7
USDA	1,959.1	1,260.9	617.7	64.4	49.0

DOD Department of Defense; DOE Department of Energy; FFRDC federally funded research and development center; HHS Department of Health and Human Services; NASA National Aeronautics and Space Administration; USDA Department of Agriculture

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development, Fiscal Years 2001, 2002, and 2003* (Arlington, VA, forthcoming).

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[41] Legislation allowing cooperative research and development agreements between private companies and Federal laboratories complemented revised antitrust regulations intended to foster intercompany collaborative R&D.

[42] See appendix table 4-26 for a list of FFRDCs, including R&D funding, location, sponsoring agency, and administrator, as of FY 2001. In general, FFRDCs may or may not be owned by the Federal Government, but most of the largest FFRDCs, such as the Department of Energy's (DOE's) FFRDCs, are owned by the Federal Government.

Table 4-15
Federal technology transfer indicators for selected agencies: FY 2001

	Inventions disclosed		Patent applications		Patents issued	
Federal agency	Number	Percent distribution	Number	Percent distribution	Number	Percent distribution
All 10 reporting	3,909	100.0	2,172	100.0	1,608	100.0
Top 5	3,780	96.7	2,090	96.2	1,566	97.4
DOD	1,005	25.7	809	37.2	619	38.5
DOE	1,527	39.1	792	36.5	605	37.6
HHS	434	11.1	255	11.7	119	7.4
NASA	696	17.8	151	7.0	159	9.9
USDA	118	3.0	83	3.8	64	4.0

DOD Department of Defense; DOE Department of Energy; HHS Department of Health and Human Services; NASA National Aeronautics and Space Administration; USDA Department of Agriculture

SOURCE: U.S. Department of Commerce, Office of the Secretary, *Summary Report on Federal Laboratory Technology Transfer; 2002 Report to the President and the Congress Under the Technology Transfer and Commercialization Act,* 2002. See appendix table 4-38.

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Federal Technology Transfer Trends

Since FY 1987, 10 Federal agencies have reported data on technology transfer to the DOC, pursuant to Federal technology transfer statutes (U.S. DOC 2002).[43] The 10 agencies reporting data were DOC, DOD, DOE, DOI, the Department of Transportation, the Environmental Protection Agency, HHS, NASA, USDA, and the Department of Veterans Affairs. In general, available metrics indicate an increased level of Federal technology transfer activities since the late 1980s. Data include inventions disclosed, federally owned patents, licenses, licensing income, and the number of CRADAs.

In FY 2001, Federal agencies reporting data on technology transfer activities logged more than 3,900 invention disclosures (table 4-15). Invention disclosures increased 9.7 percent from FY 2000, close to the 4,000 mark reached in the early and mid-1990s (figure 4-17). Patent applications increased to a peak of 2,172 in FY 2001, up 4.3 percent from FY 2000, after remaining at or just below 2,000 for most of the 1990s. Patents issued to these Federal agencies reached 1,608 in FY 2001, up 15.6 percent from FY 2000. Between FY 1997 (the first fiscal year for which these data were available from DOC) and FY 2001, a total of 7,178 patents were issued to these 10 Federal agencies.

At the agency level, DOD and DOE had the largest shares of inventions disclosed, patent applications, and patents issued in FY 2001. These two agencies accounted for 65–75 percent of those Federal technology transfer indicators among the reporting agencies. Differences in R&D funding structures and character of work may drive some of these results at the agency level. Furthermore, Federal agencies are engaged in other technology-related activities (e.g., technology procurement, safety or material standards, and technology assistance to businesses), offering other venues for technology diffusion not covered in this section.

Federal Laboratories in Collaborative Research Agreements

Two indicators of Federal laboratories' participation in research alliances show selected features of these activities: the first identifies their industrial focus, and the second describes Federal agency participation in CRADAs.

Ninety-nine R&D agreements registered from 1985 to 2001 in the *Federal Register* (11.5 percent of 861 R&D agreements) had at least one Federal laboratory partner.[44] Thirty-seven of these industry-government R&D alliances were classified in electronic and other electrical equipment and components manufacturing.[45] Ten alliances were classified in chemicals manufacturing (which includes pharmaceuticals), another 10 in industrial machinery and computer equipment manufacturing, and eight in transportation equipment manufacturing. Leyden and Link (1999) report that registered alliances with Federal laboratory partners tend to have more participants than do alliances without government partners. Federal laboratories in large alliances not only increase economies of technological scope but also reduce monitoring costs, increasing potential benefits to all members (Leyden and Link 1999).[46]

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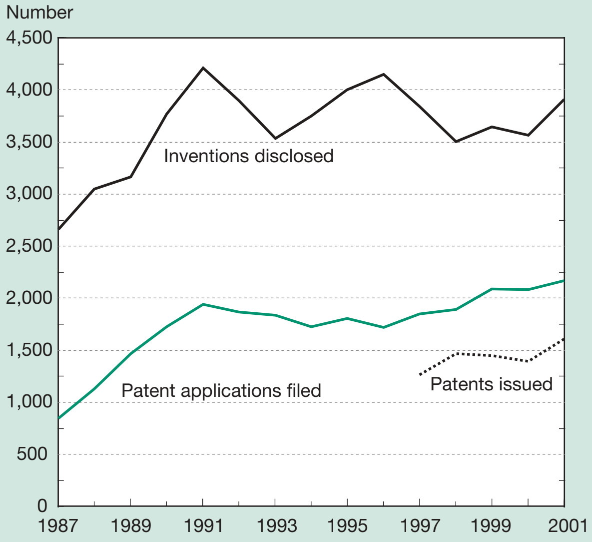
[43] Data for FY 2001 (discussed below) may not be comparable to earlier years due to changes in data reporting or scope. In particular, data from some agencies include more subcomponents or laboratories than previous years. See also Technology Transfer and Commercialization Act of 2000 in sidebar "Major Federal Legislation Related to Cooperative R&D and Technology Transfer" and U.S. General Accounting Office, *Intellectual Property—Federal Agency Efforts in Transferring and Reporting New Technology,* GAO-03-47 (Washington, DC, 2002).

[44] Cooperative Research (CORE) database, unpublished tabulations compiled by A. N. Link, University of North Carolina-Greensboro. See also "Domestic and International Technology Alliances."

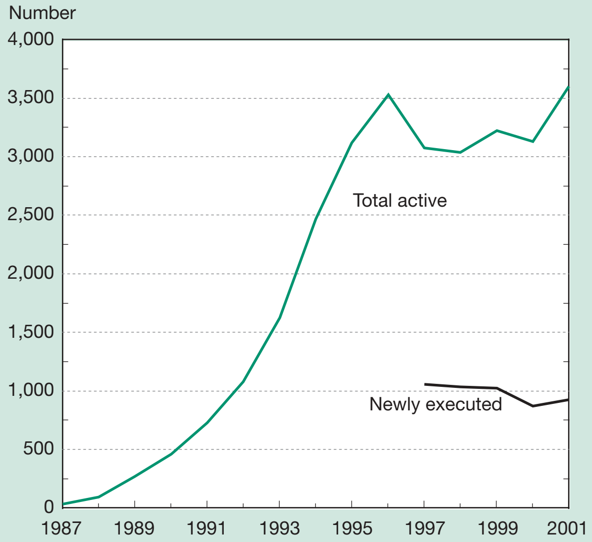
[45] These 37 alliances represented 47 percent of the 78 industry-government alliances identified by Standard Industrial Classification (SIC) code in the CORE database for the 1985–2001 period.

[46] For studies on the performance or industrial impacts of industry-government alliances, see B. Bozeman and D. Wittmer, Technical roles and success of U.S. Federal laboratory-industry partnerships, *Science and Public Policy* 28, no. 4 (2001):169–178 and J. D. Adams, E. P. Chiang, and J. L. Jensen, The influence of Federal laboratory R&D on industrial research, Working Paper 7612 (Cambridge, MA: National Bureau of Economic Research, 2000).

Figure 4-17
Federal technology transfer indicators: FY 1987–2001



Inventions and patents



CRADAs

CRADA cooperative research and development agreement

NOTE: Data for patents issued and newly executed CRADAs were not collected prior to FY 1997.

SOURCE: U.S. Department of Commerce, Office of the Secretary, *Summary Report on Federal Laboratory Technology Transfer: 2002 Report to the President and the Congress Under the Technology Transfer and Commercialization Act*, 2002. See appendix table 4-38.

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The 10 Federal agencies reporting technology transfer activities to DOC executed 926 new CRADAs with industrial and university partners in FY 2001, up 5.9 percent from FY 2000, but little changed from the 1,000 mark since first reported in FY 1997. The 2001 increase brought the number of active CRADAs to 3,603 (figure 4-17). Three agencies accounted for more than 80 percent of active CRADAs in FY 2001: DOD, which participated in 1,965 CRADAs, or 54.5 percent of all CRADAs; DOE, which participated in 558, or 15.4 percent; and HHS, which participated in 490, or 13.6 percent.

The FY 2001 increase in active CRADAs was driven by increases in DOD and HHS CRADAs (44 and 12 percent, respectively) compared with a 19 percent decline in DOE CRADAs.[47] DOE had the largest share of CRADAs through the mid-1990s, driving the overall agency count to its FY 1996 peak, when CRADAs began their declining trend. Smaller increases in DOD CRADAs sustained the overall trend from further declines to FY 2000. Compared with other forms of technology transfer activities, cooperative research activities, both CRADAs and non-CRADA joint R&D projects, involve a number of additional managerial and organizational requirements for both agency and company participants. For agencies, an additional factor is the R&D or administrative budget devoted to technology transfer planning and management (U.S. GAO 2002).

Small Business S&T Programs

The Small Business Innovation Research (SBIR) program, created in 1982 (Public Law 97-219), leverages existing Federal R&D funding toward small companies (those with 500 or fewer employees).[48] Although larger firms dominate R&D performance in the United States, as discussed earlier in this chapter, small firms may have capabilities or incentives to innovate, which may or may not come to fruition due to a number of constraints, including financing.[49] SBIR's sister program, the Small Business Technology Transfer Program (STTR), was created in 1992 to stimulate cooperative R&D and technology transfer involving small businesses and nonprofit organizations, including universities and FFRDCs. Both programs leverage existing Federal R&D funding to small-company and nonprofit performers to stimulate innovation, technology transfer, and R&D commercialization.[50] SBIR and STTR are administered by participating agencies and coordinated by the Small Business Administration.

In SBIR, Federal agencies with extramural R&D obligations exceeding $100 million must set aside a fixed percentage of such obligations for SBIR projects. This set-aside has

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[47] Recall that FY 2001 data may not be comparable to earlier years due to changes in data reporting or scope.

[48] The SBIR program was last reauthorized in December 2000 for the period through September 2008 (Public Law 106-554). This bill also requested that the National Research Council conduct a new 3-year SBIR study at five Federal agencies with SBIR budgets exceeding $50 million (DOD, Department of Health and Human Services, NASA, DOE, and NSF) to provide an assessment of SBIR's operations and impacts. The study is currently in progress. For a summary of previous policy and empirical studies, see J. Lerner and C. Kegler, Evaluating the SBIR: A literature review, In *The SBIR Program: An Assessment of the Department of Defense Fast Track Initiative* (Washington, DC: National Academy Press, 2000).

[49] For example, internal funds have been shown to significantly affect R&D activity conducted by small high-technology firms. See C. P. Himmelberg and B. C. Petersen, R&D and internal finance: A panel study of small firms in high-tech industries, *The Review of Economics and Statistics* 76, no. 1 (1994): 38–51.

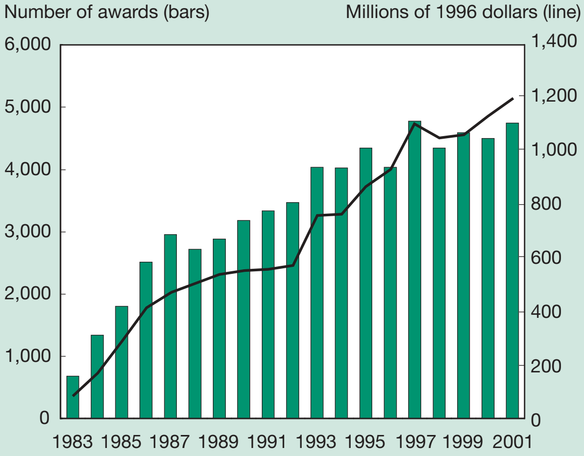
[50] The Small Business Technology Transfer Program was created by the Small Business Research and Development Enhancement Act of 1992 (Public Law 102-564). It was last reauthorized in October 2001 for the period through FY 2009 (Public Law 107-50).

been 2.5 percent since FY 1997. To obtain this Federal funding, a small company applies for a Phase I SBIR grant of up to $100,000 for up to 6 months to assess the scientific and technical feasibility of ideas with commercial potential. If the concept shows further potential, the company can receive a Phase II grant of up to $750,000 over a period of up to 2 years for further development. In Phase III, the innovation must be brought to market with private-sector investment and support; no SBIR funds may be used for Phase III activities.

SBIR awarded about $12 billion to 64,300 projects through FY 2001. Projects included research and commercialization activities in the areas of computers, information processing and electronics, materials, energy, environmental protection, and life sciences. In FY 2001 the program awarded $1.29 billion in R&D funding ($1.18 billion in 1996 dollars) to 4,748 projects (figure 4-18). In FY 2001, DOD led the 10 participating agencies in SBIR funding, obligating $576 million (45 percent of total SBIR funding), followed by HHS at $412 million (32 percent) in FY 2001 (appendix table 4-39).

STTR involves cooperative R&D performed jointly by a small business and a research organization and is also structured in three phases. The participating research organization must be a nonprofit institution, as defined by the Stevenson-Wydler Technology Innovation Act of 1980, or an FFRDC. Five Federal agencies with extramural R&D budgets exceeding $1 billion participate in the program: DOD, NSF, DOE, NASA, and HHS. The required set-aside has been 0.15 percent from FY 1996 to FY 2003, compared with 2.5 percent for SBIR.[51] STTR awarded about $460 million to more than 2,400 projects from FY 1994 to FY 2001, including $71.3 million ($65.1 million in 1996 dollars) to 337 projects in 2001. DOD and HHS are the largest agency participants (appendix table 4-40).

Figure 4-18
SBIR awards and funding: 1983–2001



SBIR Small Business Innovation Research

SOURCE: U.S. Small Business Administration, *Small Business Innovation Research Program Annual Report,* various years. See appendix table 4-39.

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The Advanced Technology Program

The Advanced Technology Program (ATP), sponsored by DOC's National Institute of Standards and Technology (NIST), was established by the Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418; 15 USC, Section 278n) to promote the development and commercialization of generic or broad-based technologies. The program provides funding for high-risk R&D projects through a competitive process on a cost-share basis with private-company participants.

From ATP's inception through FY 2002 more than 1,300 companies, nonprofit institutions, and universities participated in 642 projects costing $3.8 billion, which were funded about equally by ATP and industry (appendix table 4-41). Over the same period, 447 projects (70 percent) were single-company projects and 195 (30 percent) were joint ventures; two-thirds of participants were members of joint ventures. Participants pursued projects in five technology areas: biotechnology, electronics, IT, advanced materials and chemistry, and manufacturing.

In FY 2002, 61 R&D projects costing $289 million were initiated, with about 54 percent funded by ATP and the balance funded by participants. Public Law 108-7 appropriated $180 million for the program for FY 2003, a decline of 2.4 percent from FY 2002 (Schacht 2003). At the time of this writing, the Bush administration's FY 2004 budget calls for the suspension of new awards and requests funding only for administrative and close-out expenses (U.S. OMB 2003a).

Domestic and International Technology Alliances

Over the past 2 decades, U.S. firms have not only turned to technology outsourcing but also increased their participation in technology alliances domestically and globally. *Technology alliances* can be defined as collaborative relationships or partnerships among legally distinct parties that involve joint R&D or technology development activities.[52]

Technology alliances allow firms to share R&D costs, pool technical and market risks, and complement and further develop internal capabilities (Vonortas 1997). Collaborative networks are not without risks, however. Unintended transfer of proprietary technology is always a concern for businesses. Cultural differences among different industries, public partners (government or academic), or international partners present additional difficulties in managing alliances. Lastly, public-private collaboration presents challenges for intellectual property policy and concerns for the free flow of basic scientific knowledge.[53]

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[51] The Small Business Technology Transfer Program's set-aside percentage is scheduled to increase to 0.3 percent from FY 2004 forward (Public Law 107-50). For further details on this program, see U.S. GAO (2001a).

[52] In principle, alliances differ from external sourcing of existing technologies, such as patent licensing or contract R&D, in that the former involve some kind of joint R&D activity. In practice, however, a single technology project may involve both of these broad types of linkages.

[53] For example, see M. P. Feldman, I. Feller, J. E. L. Bercovitz, and R. M. Burton, Understanding evolving university-industry relationships, In M. P. Feldman and A. Link, eds., *Technology Policy for the Knowledge-Based Economy* (Boston: Kluwer Academic Press, 2001).

Types of Technology Alliances

Technology alliances can be classified and analyzed according to several criteria (Hagedoorn, Link, and Vonortas 2000). In terms of their organizational structure, they can be classified as *equity alliances,* or research joint ventures (RJVs), in which two or more partners form a separate business entity with long-term objectives. In contrast, *nonequity alliances* are mostly contractual agreements governing short-term projects. By membership profile, they may be private-private alliances (involving only business partners such as suppliers, customers, or competitors) or public-private alliances (involving government laboratories and universities).

Technology alliances may focus on a number of innovation-related activities, ranging from industrywide issues such as basic or precompetitive research, standards settings, or regulatory issues (Tassey 1997) to firm-specific projects. They can also range from longer term learning and capabilities-building activities to shorter term development projects closer to commercialization goals. These varied goals, together with firm-specific characteristics (e.g., size, age, internal organization, and R&D capabilities) and the underlying technology and market characteristics, affect the choice of partners and the organizational structure of these alliances.

Dedicated databases tracking these developments and sponsored in part by NSF include the Cooperative Research (CORE) database, housed at the University of North Carolina at Greensboro, and the Cooperative Agreements and Technology Indicators database, compiled by the Maastricht Economic Research Institute on Innovation and Technology (CATI-MERIT). The CORE database covers U.S.-based alliances and RJVs recorded in the *Federal Register,* pursuant to the provisions of the National Cooperative Research Act, as amended.[54] Trends in the CORE database are illustrative only, because the registry is not intended to be a comprehensive count of cooperative activity by U.S.-based firms. The CATI-MERIT database covers international technology agreements and is based on announcements of alliances and tabulated according to the country of ownership of the parent companies involved.[55]

Domestic Research Partnerships

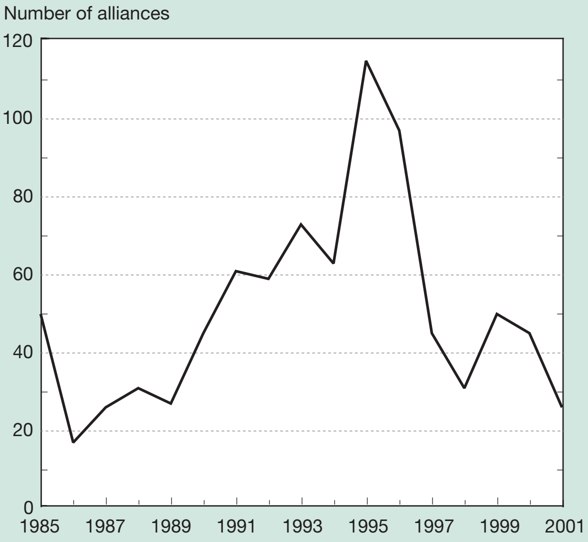
A total of 861 technology alliances were registered in the CORE database from 1985 to 2001. The database shows the following trends:

- In 2001 there were 26 new technology alliances, compared with 45 in 2000. New filings increased between 1986 and 1995, when they peaked at 115 (figure 4-19). Brod and Link (2001) developed a statistical model to explain the trends in RJV filings, including the decline after 1995. They found that filings are likely to be countercyclical. In particular, they argue that "[w]hen the economy is strong and…R&D is growing, firms may rely less on cooperative research arrangements…than when the economy is weak and internal resources are more constrained" (p. 109).
- About half of the technology alliances in 1985–2001 involved activities classified in three industrial areas: electronic and electrical equipment (18 percent), communication services (16 percent), and transportation equipment (15 percent).
- Fifteen percent (125 of 861) of these alliances involved a U.S. university as a research member, whereas about 12 percent (99 of 861) included a Federal laboratory.

International Technology Alliances

The data from the CATI-MERIT database are annual counts of new technology alliances formed by domestic and multinational corporations and their subsidiaries or affiliates worldwide. Most of the alliances recorded in the database were owned by, and/or had R&D partners located in, the

Figure 4-19
Domestic technology alliances: 1985–2001



NOTE: Data are annual counts of new technology alliances registered under the National Cooperative Research and Production Act.

SOURCE: University of North Carolina–Greensboro, Cooperative Research (CORE) database, special tabulations.

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[54] Cooperative Research (CORE) database, unpublished tabulations compiled by A. N. Link, University of North Carolina–Greensboro. Restrictions on multifirm cooperative research relationships were loosened by the National Cooperative Research Act (NCRA) in 1984 (Public Law 98-462) after concerns about the technological leadership and international competitiveness of American firms in the early 1980s. This law was enacted to encourage U.S. firms to collaborate on generic, precompetitive research. However, to gain protection from antitrust litigation, NCRA requires firms engaging in research joint ventures (RJVs) to register them with the Department of Justice. In 1993 the National Cooperative Research and Production Act (NCRPA, Public Law 103-42) extended legal protection to collaborative production activities.

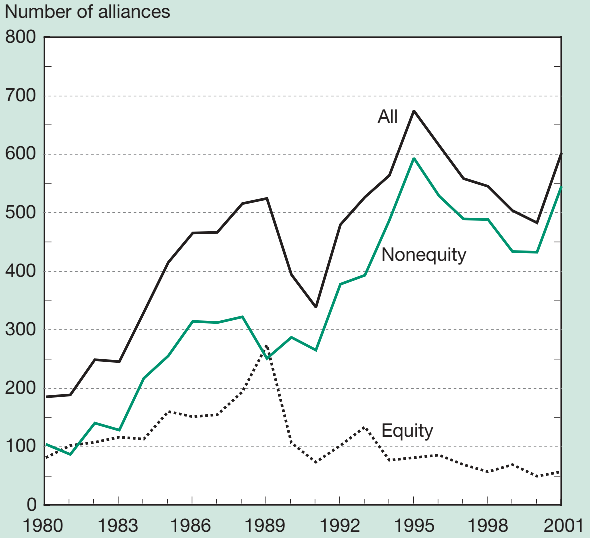
[55] The Cooperative Agreements and Technology Indicators (CATI) database is compiled by the Maastricht Economic Research Institute on Innovation and Technology (MERIT) in the Netherlands. CATI is a literature-based database that draws on sources such as newspapers, journal articles, books, and specialized journals that report on business events. Agreements involving small firms and certain technology fields are likely to be underrepresented. Another limitation is that the database draws primarily from English-language materials.

United States, Western Europe, and Japan, the so-called Triad regions.[56]

From 1991 to 2001, there were 5,892 new technology alliances formed worldwide in six major sectors: information technology (IT), biotechnology,[57] advanced materials, aerospace and defense, automotive, and (nonbiotech) chemicals. This total includes 602 alliances formed in 2001, a 25 percent increase from 483 in 2000 (figure 4-20). This is the first increase since a 19.5 percent increase in 1995 to its all-time high of 674 technology alliances.

The majority of these alliances were organized as nonequity, or contractual, agreements (figure 4-20). In particular, the share of nonequity alliances increased from 61 percent in 1980–90 to 86 percent in 1991–2001. The more flexible and project-based organization of nonequity agreements favors activities in highly dynamic high-technology sectors such as IT and biotechnology research and product development, as opposed to more mature technology sectors (Hagedoorn 2001). Indeed, these two sectors are the top technology sectors of these alliances.

Figure 4-20
International technology alliances worldwide, by type of alliance: 1980–2001



NOTE: Data are annual counts of new technology alliances worldwide.

SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Cooperative Agreements and Technology Indicators database, special tabulations. See appendix table 4-42.

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The participation by U.S.-owned companies and their subsidiaries is considerable. About 80 percent (4,646 of 5,892) of the 1991–2001 technology alliances worldwide involved at least one U.S.-owned company (table 4-16), up from two-thirds between 1980 and 1990. About half of the U.S. alliances between 1991 and 2001 (or 39 percent of the all countries total) were alliances exclusively among U.S.-owned companies. Thirty-four percent of the U.S. alliances (27 percent of the total) were formed between U.S.- and European-owned companies. European companies participated in 2,604 (44 percent of 5,892) technology alliances during the period 1991–2001, up from 1,989 alliances in 1980–1990. However, contrary to the pattern for U.S. companies, the majority of European technology alliances were between U.S.- and European-owned companies, as opposed to alliances exclusively among European-owned companies and subsidiaries. Japanese companies participated in 779 technology alliances worldwide between 1991 and 2001, down from 1,013 alliances between 1980 and 1990, according to the CATI-MERIT database.

IT was the major focus among most ownership categories shown in table 4-16 during 1990–2001. Notably, 46 percent of the alliances owned exclusively by U.S. companies in 1991–2001 were focused on IT activities. In contrast, the most frequent technology activity of U.S.-European alliances was biotechnology at 33 percent (table 4-16). (The IT share for U.S.-European alliances was the second largest at 21 percent.) Indeed, biotechnology alliances began to outpace IT alliances in 2000 (figure 4-21), driven by intense activity in this sector by U.S. and European companies (van Beuzekom 2001). In 1995 a new breed of alliance combining IT and biotechnology activities emerged in the database. From 1995 to 2001, a total of 46 alliances performed activities in areas such as bioinformatics applications. U.S. companies participated in 37 (80 percent) of these alliances, including 19 with European firms.

International R&D Trends and Comparisons

Increasingly, the international competitiveness of a modern economy is defined by its ability to generate, absorb, and commercialize knowledge. Most nations have accepted that economic policy should focus not only on improving quality and efficiency but also on promoting innovation. Absolute levels of R&D expenditures are important indicators of a nation's innovative capacity and are a harbinger of future growth and productivity. Indeed, investments in the R&D enterprise strengthen the technological base on which

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[56] The country assignment for the data subsequently discussed is based on the headquarters of the ultimate parent company of the alliance members, not on the location of the members. Classification by technology is not exclusive because an alliance may perform activities and be classified in more than one technology. The data were revised from previous editions to include exclusively joint research or development agreements, R&D contracts, equity joint ventures, and research corporations. Previous counts included cross-holdings (where two companies take a minority interest in each other), mutual second sourcing, and cross-licensing agreements. This change, however, did not affect overall trends. Separately, the data now provide detail on the structure of the alliances in terms of equity and nonequity arrangements. For conceptual, policy, and measurement issues regarding indicators of technology alliance, see J. de la Mothe and A. N. Link, *Networks, Alliances, and Partnerships in the Innovation Process* (Boston: Kluwer Academic Press, 2002); J. E. Jankowski, A. N. Link, and N. S. Vonortas, *Strategic Research Partnerships: Proceedings From an NSF Workshop*, NSF 01-336 (Arlington, VA: National Science Foundation, 2001); and B. Bozeman and J. S. Dietz, Strategic research partnerships: Constructing policy-relevant indicators, *Journal of Technology Transfer* 26 (2001):385–393.

[57] This technology classification includes pharmaceutical biotechnology.

Table 4-16
International technology alliances worldwide, by regional ownership and technology focus: 1991–2001

Ownership categories	All technologies	Information technology	Biotechnology
		Counts	
Alliances by companies from all countries	5,892	2,471	1,829
U.S.-owned only	2,297	1,133	699
U.S.-Europe owned	1,562	516	609
Europe-owned only	637	154	217
U.S.-Japan owned	439	259	93
U.S.-NT owned	348	159	90
Europe-NT owned	213	59	60
Europe-Japan owned	192	86	32
Japan-owned only	96	55	8
NT-owned only	56	20	15
Japan-NT owned	52	30	6
Selected groupings			
Alliances by U.S. companies	4,646	2,067	1,491
Alliances by European companies	2,604	815	918
Alliances by Japanese companies	779	430	139
Alliances by NT companies	669	268	171
		Percent distribution	
Ownership profile			
Alliances by companies from all countries	100	100	100
U.S.-owned only	39	46	38
U.S.-Europe owned	27	21	33
Europe-owned only	11	6	12
U.S.-Japan owned	7	10	5
U.S.-NT owned	6	6	5
Europe-NT owned	4	2	3
Europe-Japan owned	3	3	2
Japan-owned only	2	2	0
NT-owned only	1	1	1
Japan-NT owned	1	1	0
Selected groupings			
Alliances by U.S. companies	79	84	82
Alliances by European companies	44	33	50
Alliances by Japanese companies	13	17	8
Alliances by NT companies	11	11	9
Technology profile			
Alliances by companies from all countries	100	42	31
U.S.-owned only	100	49	30
U.S.-Europe owned	100	33	39
Europe-owned only	100	24	34
U.S.-Japan owned	100	59	21
U.S.-NT owned	100	46	26
Europe-NT owned	100	28	28
Europe-Japan owned	100	45	17
Japan-owned only	100	57	8
NT-owned only	100	36	27
Japan-NT owned	100	58	12
Selected groupings			
Alliances by U.S. companies	100	44	32
Alliances by European companies	100	31	35
Alliances by Japanese companies	100	55	18
Alliances by NT companies	100	40	26

NT non-Triad (country or region other than United States, Europe, and Japan)

NOTES: Percents may not sum to total because of rounding. Data are annual counts of new technology alliances formed by domestic and multinational corporations worldwide. Alliances may be classified in more than one technology. Country assignment is based on headquarters of ultimate parent company of alliance members, not on location of members. Data were revised from previous editions to include exclusively joint research or development agreements, R&D contracts, equity joint ventures, and research corporations. Previous counts included cross-holdings (two companies take minority interest in each other), mutual second sourcing, and cross-licensing agreements. This change, however, had little effect on overall trends. See appendix table 4-42.

SOURCE: Maastricht Cooperative Agreements and Technology Indicators database, Economic Research Institute on Innovation and Technology, unpublished tabulations.

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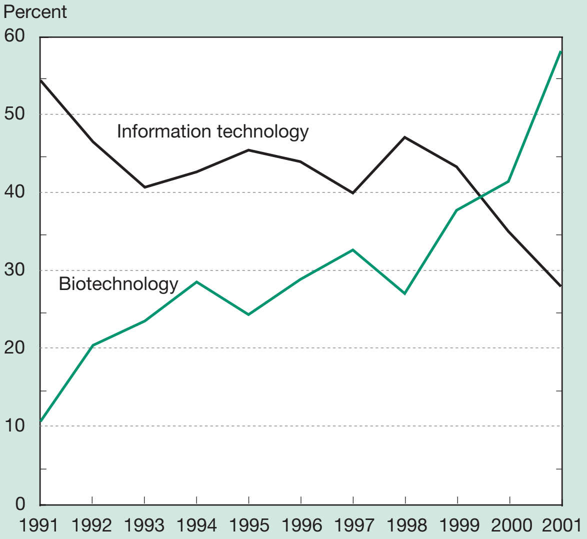
Figure 4-21

Information technology and biotechnology shares of international technology alliances: 1991–2001



SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Cooperative Agreements and Technology Indicators database, special tabulations. See appendix table 4-42.

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economic prosperity increasingly depends worldwide. The relative strength of a particular country's current and future economy and the specific scientific and technological areas in which a country excels are further revealed through comparison with other major R&D-performing countries. This section compares international R&D spending patterns. Topics include absolute and relative expenditure trends, the structure of R&D performance and funding across sectors, the foci of R&D activities within sectors, and government research-related priorities.

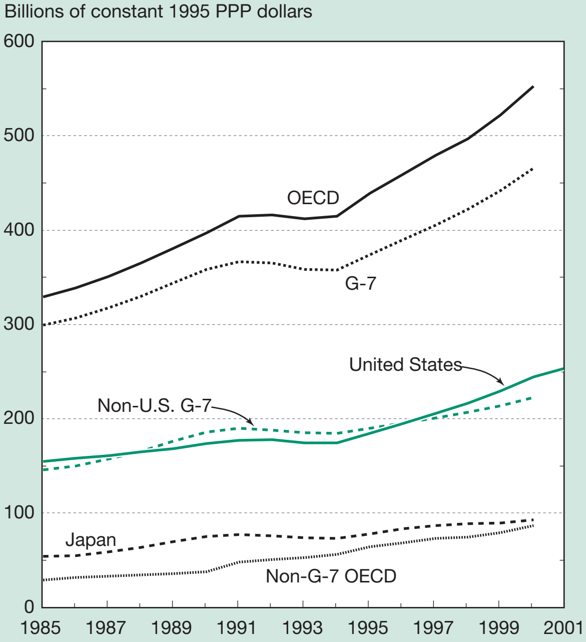
Most of the R&D data presented in this section are from reports to the Organisation for Economic Co-operation and Development (OECD), the most reliable source for such international comparisons. However, an increasing number of non-OECD countries and organizations now collect and publish internationally comparable R&D statistics, which are reported at various points in this section.

Absolute Levels of Total R&D Expenditures

Worldwide R&D performance is concentrated in a few industrialized nations. Of the $603 billion in estimated 2000 R&D expenditures for the 30 OECD countries, fully 85 percent is expended in only 7 countries (OECD 2002d).[58] These estimates are based on reported R&D investments (for defense and civilian projects) converted to U.S. dollars with purchasing power parity (PPP) exchange rates.[59] (See sidebar, "Purchasing Power Parities: Preferred Exchange Rates for Converting International R&D Data.") R&D expenditures in the United States alone account for roughly 44 percent of all OECD member countries' combined R&D investments; R&D investments in the United States are 2.7 times greater than investments made in Japan, the second largest R&D-performing country. More money was spent on R&D activities in the United States in 2000 than in the rest of the G-7 countries (Canada, France, Germany, Italy, Japan, and the United Kingdom) combined. (See figure 4-22 and appendix table 4-43 for inflation-adjusted PPP R&D totals for OECD and G-7 countries.) South Korea is the only other country that accounted for a substantial share of the OECD total (3.1 percent in 2000, which was higher than expenditures in either Canada or Italy). In only four other countries (the Netherlands, Australia, Sweden, and Spain) did R&D expenditures exceed 1 percent of the OECD R&D total (OECD 2002d).[60]

Figure 4-22

U.S., G-7, and OECD countries R&D expenditures: 1985–2001



OECD Organisation for Economic Co-operation and Development
PPP purchasing power parity

NOTE: Non-U.S. G-7 countries are Canada, France, Germany, Italy, Japan, and the United Kingdom.

SOURCE: OECD, *Main Science and Technology Indicators,* 2002. See appendix table 4-43.

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[58] Current members of the Organisation for Economic Co-operation and Development (OECD) are Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.

[59] Although purchasing power parities (PPPs) technically are not equivalent to R&D exchange rates, they better reflect differences in countries' research costs than do market exchange rates.

[60] Data for 2000 were unavailable for Sweden, but in 1999 it accounted for 1.4 percent of the OECD total.

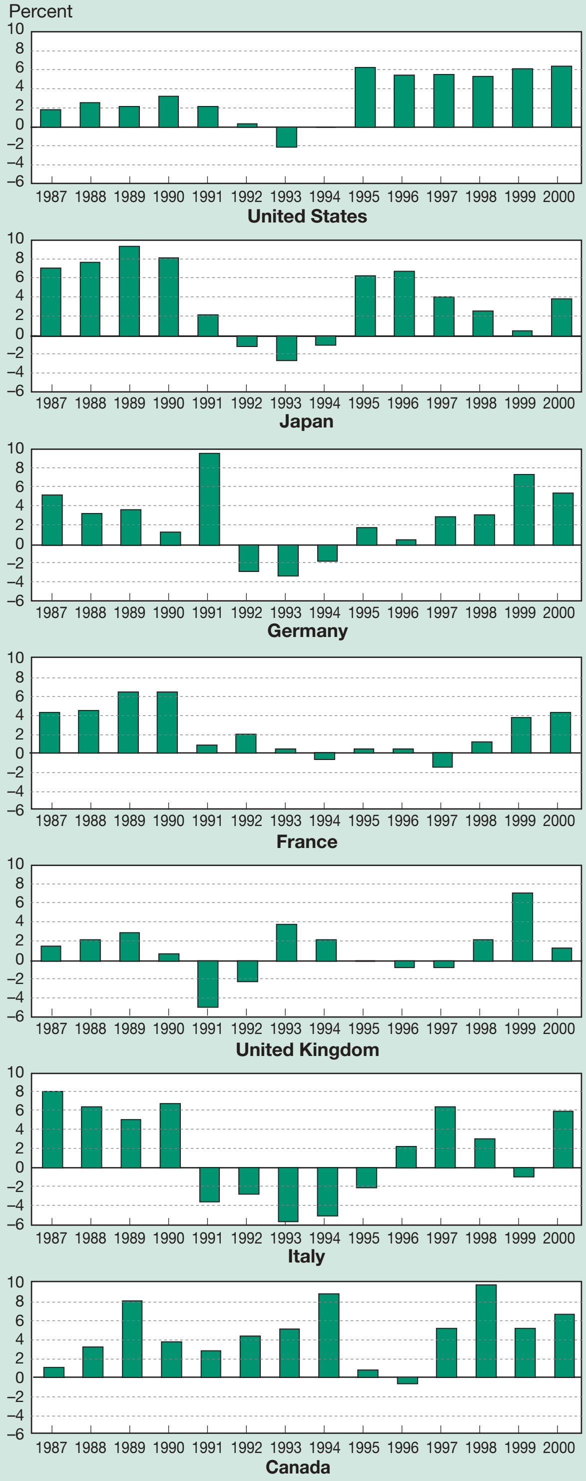
Although non-OECD countries also fund and perform R&D, most of these national R&D efforts are comparatively small. In 2000, for example, R&D expenditures in China and Russia totaled $50.3 and $10.6 billion (PPP dollars), respectively, and nondefense R&D expenditures in Israel totaled $5.6 billion (PPP dollars) (OECD 2002d). Among non-OECD members of Red Iberomericana de Indicadores de Ciencia y Tecnologia (RICYT), the largest R&D expenditures are reported for Brazil ($4.6 billion in U.S. dollars at market exchange rates in 1999), Argentina ($1.3 billion in 2000), Chile ($0.4 billion in 2000), and Colombia ($0.2 billion in 2000) (RICYT 2002). The combined R&D expenditures of these seven countries (approximately $73 billion) would raise the OECD world total by about 12 percent, and about two-thirds would be derived from China alone.

In terms of relative shares, U.S. R&D expenditures in 1984 reached historical highs of 55 percent of the G-7 total and 47 percent of the OECD total.[61] As a proportion of the G-7 total, U.S. R&D expenditures declined steadily to a low of 48 percent in 1991 and then increased to 52 percent in 2000. (See figure 4-22 for actual expenditure totals.) The U.S. share of total OECD expenditures for R&D has increased similarly. By 1994 the U.S. share had dropped to 42 percent of the OECD R&D total, partly the result of several countries joining OECD (thereby increasing the OECD R&D totals). The U.S. share climbed back to 44 percent of the OECD total by 2000 as a result of robust R&D growth in the United States.

Most of the increase in the U.S. percentage of total G-7 R&D expenditures after the early 1990s initially resulted from a worldwide slowing in R&D performance that was more pronounced in other countries. Although U.S. R&D spending stagnated or declined for several years in the early to mid-1990s, the reduction in real R&D spending in most of the other large R&D-performing countries was more striking. In Japan, Germany, and Italy, inflation-adjusted R&D spending fell for 3 consecutive years (1992, 1993, and 1994) at a rate exceeding the similarly falling rate in the United States[62] (OECD 2002d). In the late 1990s, R&D spending rebounded in several G-7 countries and in the United States. Because annual R&D growth was generally stronger in the United States than elsewhere (figure 4-23), however, the U.S. percentage of total G-7 R&D spending continued to increase. Although the slowdown in the technology market in 2001 and 2002 has had a global reach, it remains to be seen

Figure 4-23

Rate of change in total inflation-adjusted R&D spending: 1987–2000



NOTES: Data for Japanese R&D in 1996 and later years may not be consistent with data in earlier years because of changes in methodology. Germany data for 1987–90 are for West Germany.

SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators,* 2002. See appendix table 4-43.

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[61] OECD maintains R&D expenditure data that can be categorized into three periods: (1) 1981 to the present (data are properly annotated and of good quality); (2) 1973 to 1980 (data are probably of reasonable quality, and some metadata are available); and (3) 1963 to 1972 [data are questionable for most OECD countries (with notable exceptions of the United States and Japan), many of which launched their first serious R&D surveys in the mid-1960s]. The analyses in this chapter are limited to data for 1981 and subsequent years.

[62] The United Kingdom similarly experienced 3 years of declining real R&D expenditures, but its slump took place in 1995, 1996, and 1997. The falling R&D totals in Germany were partly a result of specific and intentional policies to eliminate redundant and inefficient R&D activities and to integrate the R&D efforts of the former East Germany and West Germany into a united German system.

Purchasing Power Parities: Preferred Exchange Rates for Converting International R&D Data

Comparisons of international R&D statistics are hampered because R&D expenditures are denominated in the performing country's currency. Two approaches are commonly used to normalize the data and facilitate aggregate R&D comparisons: (1) dividing R&D by GDP, which results in indicators of relative effort according to total economic activity and circumvents the problem of currency conversion, and (2) converting all foreign-denominated expenditures to a single currency, which results in indicators of absolute effort. The first method is a straightforward calculation that permits only gross national comparisons. The second method permits absolute-level comparisons and analyses of countries' sector- and field-specific R&D investments, but it entails choosing an appropriate currency conversion series.

Market Exchange Rates and Purchasing Power Parity Rates

Because (for all practical purposes) no widely accepted R&D-specific exchange rates exist, the choice is between market exchange rates (MERs) and purchasing power parities (PPPs) (OECD 2002d). These rates are the only series consistently compiled and available for a large number of countries over an extended period of time.

Market Exchange Rates. At their best, MERs represent the relative value of currencies for goods and services that are traded across borders; that is, MERs measure a currency's relative international buying power. Sizable portions of most countries' economies do not engage in international activity, however, and major fluctuations in MERs greatly reduce their statistical utility. MERs also are vulnerable to a number of distortions, including currency speculation, political events such as wars or boycotts, and official currency intervention, which have little or nothing to do with changes in the relative prices of internationally traded goods.

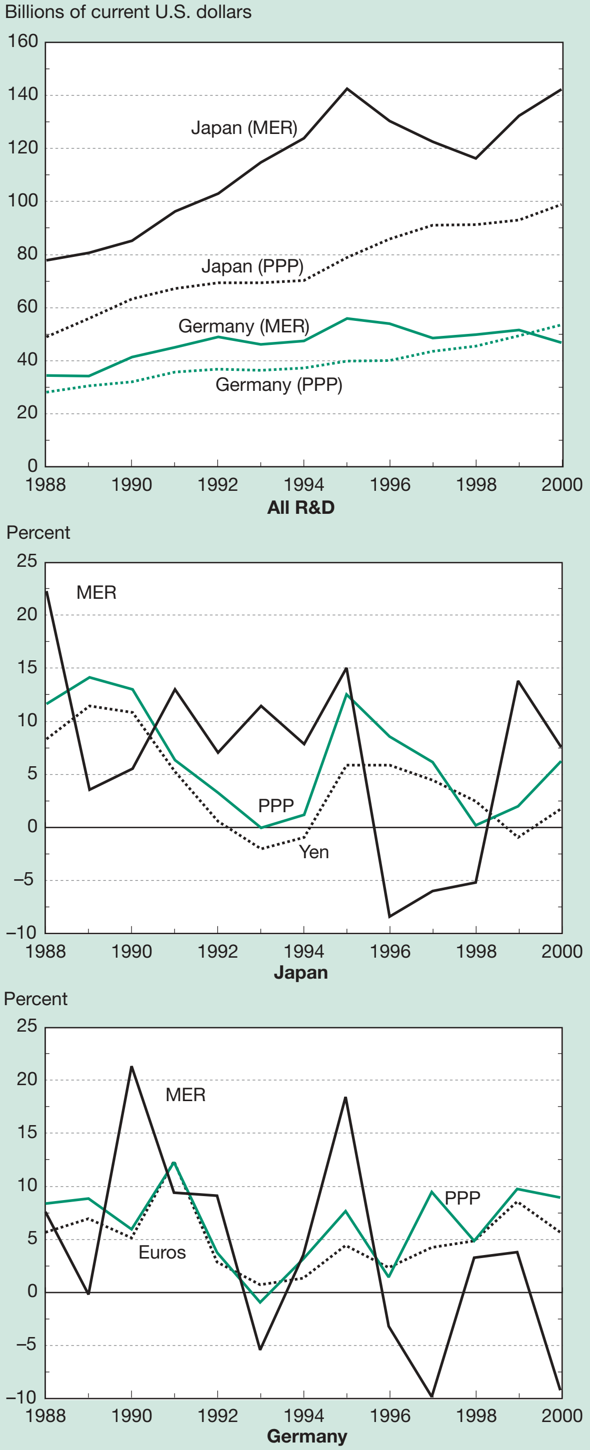
PPP Rates. Because of the MER shortcomings described above, the alternative currency conversion series of PPPs was developed (Ward 1985). PPPs take into account the cost differences across countries of buying a similar basket of goods and services in numerous expenditure categories, including nontradables. The PPP basket is, therefore, representative of total GDP across countries. When the PPP formula is applied to current R&D expenditures of other major performers, such as Japan and Germany, the result is a substantially lower estimate of total R&D spending than that given by MERs (figure 4-24). For example, Japan's R&D in 1998 totaled $91 billion based on PPPs and $116 billion based on MERs, and the German R&D expenditure was $45 billion on PPPs and $50 billion on MERs. (In comparison, the U.S. R&D expenditure was $226 billion in 1998.)

PPPs are the preferred international standard for calculating cross-country R&D comparisons wherever possible and are used in all official R&D tabulations of the Organisation of Economic Co-operation and Development (OECD). Unfortunately, they are not available for all countries and currencies. They are available for all OECD countries, however, and are therefore used in this report.

Exchange Rate Movement Effects

Although the goods and services included in the market basket used to calculate PPP rates differ from the major components of R&D costs—fixed assets as well as wages of scientists, engineers, and support personnel—they still result in a more suitable domestic price converter than one based on foreign trade flows. Exchange rate movements bear little relationship to changes in the cost of domestically performed R&D (figure 4-24). When annual changes in Japan's and Germany's R&D expenditures are converted to U.S. dollars with PPPs, they move in tandem with such funding denominated in their home currencies. Changes in dollar-denominated R&D expenditures converted with MERs exhibit wild fluctuations that are unrelated to the R&D purchasing power of those investments. MER calculations indicate that, between 1988 and 2000, German and Japanese R&D expenditures each increased twice by 15 percent or more. In reality, nominal R&D growth was only a fourth to a third of those rates in either country during this period. PPP conversions generally mirror the R&D changes denominated in these countries' home currencies.

Figure 4-24
R&D expenditures and annual changes in R&D estimates, Japan and Germany: 1988–2000



MER market exchange rate
PPP purchasing power parity

SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators,* 2002. See appendix tables 4-2 and 4-43.

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whether the sharp slowdown in U.S. R&D expenditures in 2001 and 2002 will be as pronounced internationally.

Trends in Total R&D/GDP Ratios

One of the first and now one of the more widely used indicators of a country's R&D intensity is the ratio of R&D spending to GDP (Steelman 1947) (figure 4-25). For many of the G-8 countries (that is, the G-7 countries plus Russia), the latest R&D/GDP ratio is no higher now than it was at the start of the 1990s, which ushered in a period of slow growth or decline in their overall R&D efforts.[63] The United States and Japan reached 2.7 and 2.8 percent, respectively, in 1990–91. As a result of reduced or level spending by industry and government in both countries, the R&D/GDP ratios declined several tenths of a percentage point, to 2.4 and 2.6, respectively, in 1994 before rising again to 2.7 and 3.0 percent in 2000. Growth in industrial R&D accounted for much of the recovery in each of these countries. However, the steady increase in Japan's R&D/GDP ratio in 1994–2000 is also partially a result of anemic economic conditions overall: GDP fell in both 1998 and 1999 with only a marginal increase in 2000, so that even level R&D spending resulted in a slight increase in its R&D ratio (OECD 2002d).

Among the remaining six G-8 countries, three (Germany, Canada, and Russia) display recent increases in their economy's R&D/GDP ratio, and three (the United Kingdom, France, and Italy) report an R&D/GDP ratio that has remained stable or has declined. In Germany the R&D/GDP ratio fell from 2.8 percent at the end of the 1980s, before reunification, to 2.3 percent in 1994 before rising to 2.5 percent in 2001. Canada's R&D/GDP ratio also rose in the late 1990s from 1.7 percent in 1996 to 1.9 percent in 2001. The end of the cold war and collapse of the Soviet Union had a drastic effect on Russia's R&D intensity. R&D spending in Russia was estimated at 2.0 percent of GDP in 1990; that figure plummeted to 1.4 percent in 1991 and then tumbled further to 0.7 percent in 1992. Moreover, the severity of this R&D decline is masked somewhat: although the R&D share was falling, it also was a declining share of a declining GDP. By 1999 the R&D/GDP ratio in Russia had inched back to about 1.0 percent; it accelerated to 1.2 percent in 2001 as R&D performance in the country grew by more than 30 percent in real terms over those 2 years. In comparison, the R&D/GDP ratio slipped slightly in the United Kingdom in the late 1990s to 1.9 percent in 2000. Between 1997 and 2001, the R&D/GDP ratio fluctuated narrowly at 2.2 and 1.1 percent in France and Italy, respectively.

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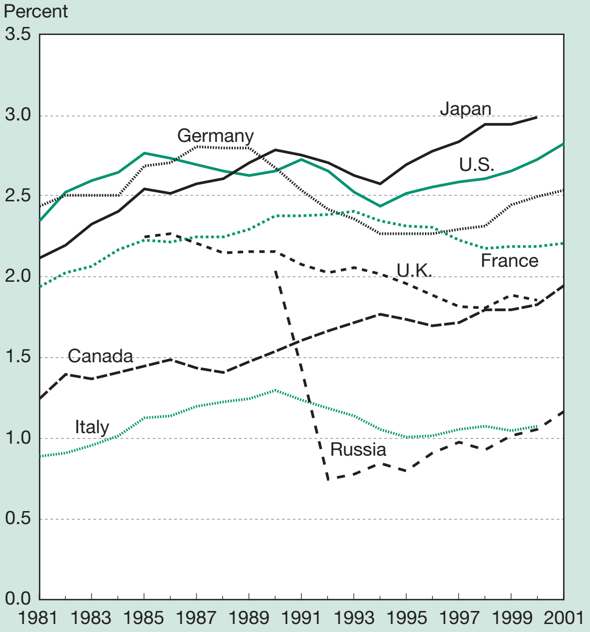
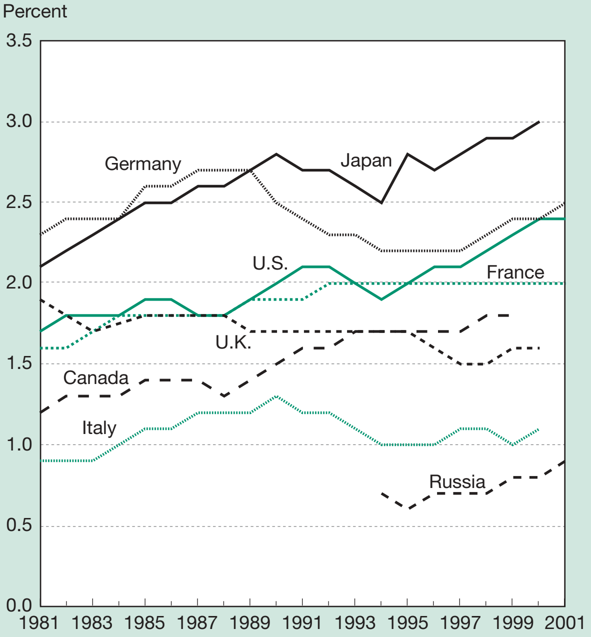
[63] A country's R&D spending and therefore its R&D/GDP ratio is a function of several factors in addition to its commitment to supporting the R&D enterprise. Especially because the majority of R&D is performed by industry in each of these countries, the structure of industrial activity can be a major determinant of a country's R&D/GDP ratio. For example, economies with high concentrations in manufacturing (which traditionally have been more R&D intensive than nonmanufacturing or agricultural economies) have different patterns of R&D spending. See "Industrial Sector" for further discussion of such considerations.

Figure 4-25
R&D share of GDP, selected countries: 1981–2001



Total R&D/GDP



Nondefense R&D/GDP

GDP gross domestic product
U.K. United Kingdom
U.S. United States

SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators,* 2002. See appendix tables 4-43 and 4-44.

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Overall, the United States ranked fifth among OECD countries in terms of reported R&D/GDP ratios (table 4-17). Israel (not an OECD member country), devoting 4.4 percent of its GDP to R&D, led all countries, followed by Sweden (3.8 percent), Finland (3.4 percent), Japan (3.0 percent), and Iceland (2.9 percent). In general, nations in Southern and Eastern Europe tend to have R&D/GDP ratios below 1.5 percent, whereas Nordic nations and those in Western Europe report R&D spending shares greater than 1.5 percent. In a broad sense, the reason for such patterns has much to do with overall funding patterns and macroeconomic structures.

In practically all OECD countries, the business sector finances most of the R&D. However, OECD countries with relatively low R&D/GDP ratios tend to be relatively low-income countries, where government funding tends to provide a larger proportion of the R&D support than it provides in countries with high R&D/GDP ratios. Furthermore, the private sector in low-income countries often has a low concentration of high-technology industries, resulting in low overall R&D spending and therefore low R&D/GDP ratios. Indeed, a strong link exists between countries with high incomes that emphasize the production of high-technology goods and services and those that invest heavily in R&D activities (OECD 2000).[64] This highlights that R&D/GDP ratios are most useful when comparing countries with national S&T systems of comparable maturity and development.

Outside the European region, R&D spending has intensified considerably since the early 1990s. Several Asian countries, most notably South Korea and China, have been particularly aggressive in expanding their support for R&D and S&T-based development. In Latin America and the Pacific region, other non-OECD countries also have attempted to increase R&D investments substantially during the past several years. Even with recent gains, however, most non-European (non-OECD) countries invest a smaller share of their economic output in R&D than do OECD members (with the exception of Israel). All Latin American countries for which such data are available report R&D/GDP ratios below 1 percent (table 4-17). This distribution is consistent with broader indicators of economic growth and wealth. However, many of these countries also report additional S&T-related expenditures on human resources training and S&T infrastructure development that are not captured in R&D or R&D/GDP data (RICYT 2002).

Nondefense R&D Expenditures and R&D/GDP Ratios

Although the R&D intensities of many countries have changed little over the past decade, there have been significant changes in the composition of their R&D. One indicator

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[64] See OECD (1999) for further discussion of these and other broad R&D indicators.

Table 4-17
R&D share of gross domestic product, by country/economy: 1997–2001

Country/economy	Percent	Country/economy	Percent
Total OECD (2000)	2.24	Italy (2000)	1.07
European Union (2000)	1.88	New Zealand (1999)	1.03
Israel (2001)	4.43	China (2000)	1.00
Sweden (1999)	3.78	Spain (2001)	0.97
Finland (2000)	3.37	Brazil (1999)	0.87
Japan (2000)	2.98	Cuba (2000)	0.82
Iceland (2001)	2.90	Hungary (2000)	0.80
United States (2001)	2.71	Portugal (1999)	0.76
South Korea (2000)	2.65	Greece (1999)	0.67
Switzerland (2000)	2.64	Poland (2001)	0.67
Germany (2001)	2.53	Slovak Republic (2001)	0.65
France (2001)	2.20	Turkey (2000)	0.64
Singapore (2001)	2.11	Chile (2000)	0.54
Denmark (1999)	2.09	Mexico (1999)	0.43
Taiwan (2000)	2.05	Argentina (2001)	0.42
Netherlands (2000)	1.97	Romania (2001)	0.40
Belgium (1999)	1.96	Panama (1999)	0.35
Canada (2001)	1.94	Bolivia (2000)	0.28
Austria (2001)	1.91	Costa Rica (1998)	0.27
United Kingdom (2000)	1.85	Uruguay (1999)	0.26
Australia (2000)	1.53	Colombia (2000)	0.24
Slovenia (2000)	1.52	Trinidad and Tobago (1997)	0.14
Norway (2001)	1.46	Nicaragua (1997)	0.13
Czech Republic (2001)	1.31	Ecuador (1998)	0.08
Ireland (1999)	1.21	El Salvador (1998)	0.08
Russian Federation (2001)	1.16	Peru (1999)	0.08

OECD Organisation for Economic Co-operation and Development

NOTES: Civilian R&D only for Israel and Taiwan. Data are presented for the latest available year, in parentheses.

SOURCES: OECD, Main Science and Technology Indicators database, 2002; and Iberomerican Network of Science and Technology Indicators, *Principales Indicadores de Ciencia y Tecnologia Argentina 2001* (Buenos Aires, 2002).

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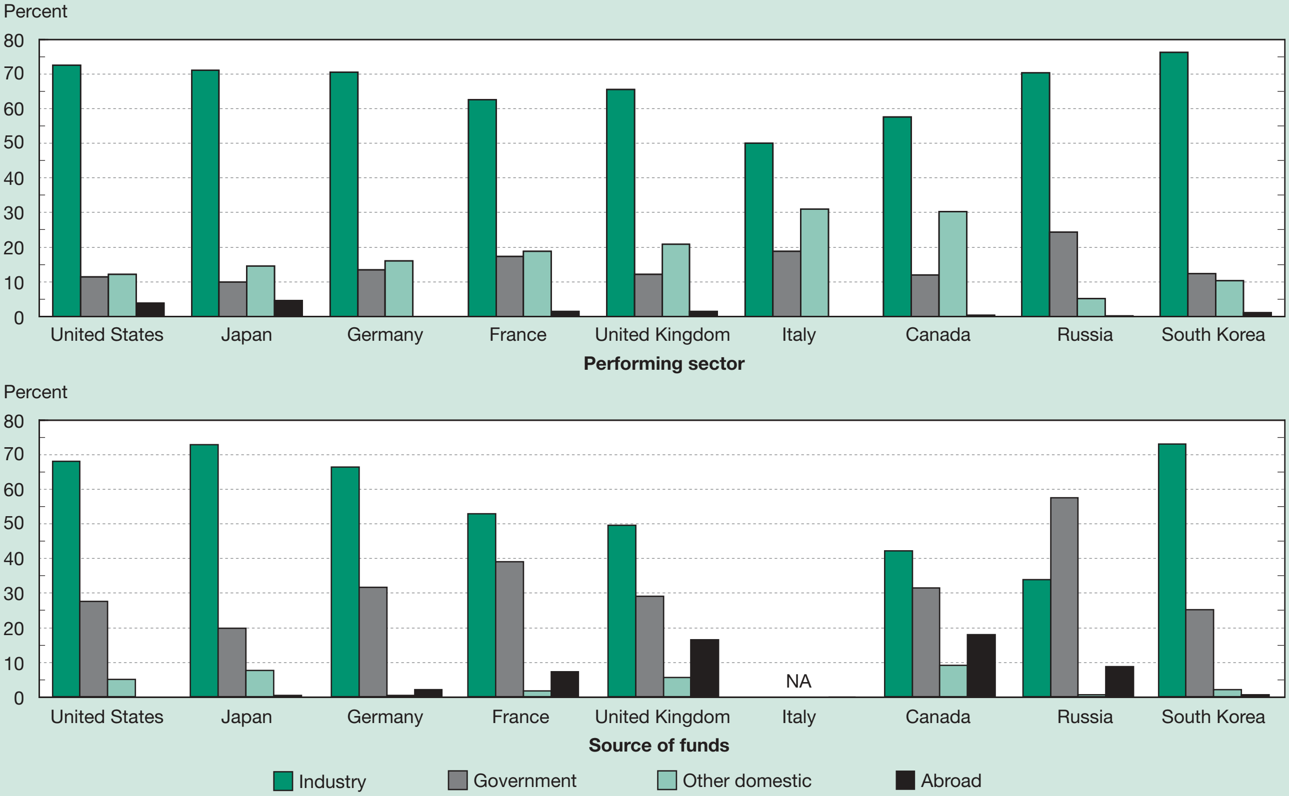
of these changes is the relative increase in nondefense R&D. Although defense-related R&D does result in spillovers that produce social benefits, nondefense R&D is more directly oriented toward national scientific progress, standard-of-living improvements, economic competitiveness, and commercialization of research results. Indeed, conclusions about a country's relative standing may differ dramatically, depending on whether total R&D expenditures include or exclude defense-related expenditures; for some countries, the relative emphasis has shifted over time. Among G-8 countries, the inclusion of defense-related R&D has had little impact on R&D totals for Japan, Germany, Italy, and Canada, where defense-related R&D represents 5 percent or less of the national total. In other countries, defense has accounted for a more significant proportion of the national R&D effort, although this proportion has generally declined since the end of the cold war. Between 1988 and 2000, the defense share of the R&D total:

- Fell from 31 to 14 percent in the United States
- Fell from 19 to 8 percent in France
- Fell from 16 to 15 percent in the United Kingdom
- Accounted for approximately 24 percent of the Russian R&D total in 2000

Consequently, if current trends persist, the distinction between defense and nondefense R&D expenditures in international comparisons may become less important. In absolute dollar terms, nondefense R&D spending is still considerably larger in the United States than in other countries. In 2000 (the latest year for which comparable international R&D data are available for most OECD countries), U.S. nondefense R&D was more than twice that of Japan's and was equivalent to 97 percent of the non-U.S. G-7 countries' combined nondefense R&D total (appendix table 4-44).

In terms of R&D/GDP ratios, the relative position of the United States is somewhat less favorable when only nondefense R&D is included in the metric. Japan's nondefense R&D/GDP ratio (3.0 percent) exceeded the U.S. ratio (2.4 percent) in 2000, as it has for years (figure 4-25 and appendix table 4-44). In 2001, Germany's nondefense R&D/GDP ratio (2.5 percent) slightly exceeded the U.S. ratio (2.4 percent). The 2001 nondefense ratio for France (2.0 percent) was slightly below the U.S. ratio. In 1999–2000, ratios for the United Kingdom (1.6 percent in 2000), Canada

Figure 4-26
R&D expenditures for selected countries, by performing sector and source of funds: 2000 or 2001



NA not available

NOTES: Separate data on foreign sources of R&D funding are unavailable for the United States but are included in the sector totals. In most other countries, “foreign sources of funding” is a distinct and separate funding category. For some countries (such as Canada), foreign firms are the source of a large amount of foreign R&D funding, which is reported as funding from abroad. In the United States, industrial R&D funding from foreign firms is reported as industry. Data for Japan, France, United Kingdom, and Italy are for 2000. Data for the United States, Germany, Canada, Russia, and South Korea are for 2001.

SOURCES: Organisation for Economic Co-operation and Development, special tabulations, 2003; and National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* annual series. See appendix table 4-45.

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(1.8 percent in 1999), and Italy (1.1 percent in 2000) were considerably lower than U.S. ratios. In 2001 the nondefense R&D/GDP ratio for Russia (0.9 percent) was less than half the U.S. ratio.

International R&D by Performer, Source, and Character of Work

R&D performance patterns by sector are broadly similar across countries, but national sources of support differ considerably. In nearly all OECD countries, government has provided a declining share of all R&D funding during the past 2 decades, and the industrial share of R&D funding has increased considerably. The emphases of industrial R&D efforts, however, differ across countries, as do governmental R&D priorities and academic S&E field research emphases, as described subsequently in this chapter.

Government and industry together account for roughly 80 percent or more of the R&D funding in each of the G-8 countries, although the respective contributions vary substantially across countries.[65] In recent years, the industrial sector provided more than 70 percent of R&D funds in Japan, 68 percent in the United States, 66 percent in Germany, 53 percent in France, 49 percent in the United Kingdom, and 44 percent in Canada[66] (figure 4-26). In Russia, industry provided approximately 34 percent of the nation’s R&D funding. Government provided the largest share of Russia’s

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[65] In accordance with international standards, the following sectors are recognized sources of funding: all levels of government combined, business enterprises, higher education, private nonprofit organizations, and funds from abroad. Because data on foreign sources of R&D funding are unavailable for the United States, the figures reported for the share of industrial R&D funding in the United States include funding from both foreign and domestic sources.

[66] Canada and the United Kingdom both report relatively large amounts of R&D funding from abroad, much of which originates from business enterprises. Therefore, industry’s shares of R&D funding for these countries are particularly understated compared with those for the United States. Distribution of R&D by source of funds was not available for Italy for 2000. In earlier years, government sources accounted for more than half of Italy’s R&D, industry accounted for more than 40 percent, and foreign sources funded the remainder.

R&D (57 percent), as it did in Italy in past years (more than 50 percent in 1999). In the remaining six countries, government was the second largest source of R&D funding, ranging from 20 percent (in Japan) to 39 percent (in France) of the total. In each of these eight countries, government provided the largest share of the funds used for academic R&D performance (appendix table 4-45).

The industrial sector dominates R&D performance in each of the G-8 countries (figure 4-26). Industry's share of R&D performance for the 2000–2001 period ranged from 50 percent in Italy to a little more than 70 percent in the United States, Japan, Germany, and Russia. During the same period, industry's share was between 57 and 66 percent in Canada, France, and the United Kingdom. Most of the industrial R&D in these countries was funded by industry. Government's share of funding for industrial R&D ranged from as little as 2 percent in Japan and Canada to 49 percent in Russia (appendix table 4-45). In the other G-8 countries, government funded between 7 and 11 percent of industrial R&D.

In all of the G-8 countries except Russia, the academic sector was the second largest R&D performer (about 12 to 31 percent of the performance total in each country).[67] Academia often is the primary location of research (as opposed to R&D) activities, however. Government was the second largest R&D performer in Russia (accounting for 24 percent of that nation's R&D effort). Government also performed a larger proportion of R&D in France, which operates some sizable government laboratories.

South Korea, with total R&D expenditures in excess of either Canada or Italy, has R&D distributions by performing sector and source of funds very similar to those of the United States. Industry performed an even greater share of South Korea's R&D (76 percent) than it did in any of the G-8 countries and was also the largest source of R&D funding in South Korea (accounting for 73 percent of all funding). The South Korean government provided most of the remaining R&D funding (25 percent of all funding). About 45 percent of government R&D funding in South Korea went to government performers of R&D, with the remainder going primarily to academic (29 percent) and industrial performers (25 percent).

Academic Sector

In many OECD countries, the academic sector is a distant second to industry in terms of national R&D performance. Among G-8 countries, universities accounted for as little as 5 percent of Russia's R&D total to more than 31 percent of Italy's.[68]

Source of Funds. For most of these countries, the government is now, and historically has been, the largest source of academic research funding. However, in each of the G-8 countries for which historical data exist (except Russia), the government's share has declined during the past 20 years, and industry's share has increased. Specifically, the government's share, including both direct government support for academic R&D and the R&D component of block grants to universities, has fallen by 8 percentage points or more in five of the G-7 countries since 1981 (except in France and Italy, where the government's share of academic R&D dipped by 6 and 2 percentage points, respectively).[69] In comparison, and as an indication of an overall pattern of increased university-firm interactions (often intending to promote the commercialization of university research), the proportion of academic R&D funded by industry for these seven countries combined climbed from 2.6 percent of the academic R&D total in 1981 to 5.2 percent in 1990 and to 6.0 percent in 1999. In Germany, more than 11 percent of university research was funded by industry in 2000 (table 4-18).

S&E Fields. Most countries supporting a substantial level of academic R&D (at least $1 billion PPPs in 1999) devote a larger proportion of their R&D to engineering, social sciences, and humanities than does the United States[70] (table 4-19). Conversely, the U.S. academic R&D effort emphasizes the medical sciences and natural sciences relatively more than do many other OECD countries.[71] The latter observation is consistent with the emphases in health and

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[67] The national totals for Europe, Canada, and Japan include the research component of general university fund (GUF) block grants (not to be confused with basic research) provided by all levels of government to the academic sector. Therefore, at least conceptually, the totals include academia's separately budgeted research and research undertaken as part of university departmental R&D activities. In the United States, the Federal Government generally does not provide research support through a GUF equivalent, preferring instead to support specific, separately budgeted R&D projects. On the other hand, a fair amount of state government funding probably does support departmental research at public universities in the United States. Data on departmental research, considered an integral part of instructional programs, generally are not maintained by universities. U.S. totals are thus underestimated relative to the R&D effort reported for other countries.

[68] Country data are for 2000 or 2001 (appendix table 4-45).

[69] Whereas GUF block grants are reported separately for Japan, Canada, and European countries, the United States does not have an equivalent GUF category. In the United States, funds to the university sector are distributed to address the objectives of the Federal agencies that provide the R&D funds. Nor is GUF equivalent to basic research. The treatment of GUF is one of the major areas of difficulty in making international R&D comparisons. In many countries, governments support academic research primarily through large block grants that are used at the discretion of each individual higher education institution to cover administrative, teaching, and research costs. Only the R&D component of GUF is included in national R&D statistics, but problems arise in identifying the amount of the R&D component and the objective of the research. Government GUF support is in addition to support provided in the form of earmarked, directed, or project-specific grants and contracts (funds for which can be assigned to specific socioeconomic categories). In the United States, the Federal Government (although not necessarily state governments) is much more directly involved in choosing which academic research projects are supported than are national governments in Europe and elsewhere. In each of the European G-7 countries, GUF accounts for 50 percent or more of total government R&D to universities and for roughly 45 percent of the Canadian government academic R&D support. Thus, these data indicate not only relative international funding priorities but also funding mechanisms and philosophies regarding the best methods for financing research.

[70] The national emphases in particular S&E fields differ across countries. Most of the internationally comparable data on field-specific R&D are reported for the academic sector.

[71] In international S&E field compilations, the natural sciences comprise math and computer sciences, physical sciences, environmental sciences, and all life sciences other than medical and agricultural sciences. Note also that the U.S. academic R&D effort is considerably larger than in any other country and that the U.S. total ($26 billion PPP) is comparable to the combined R&D total ($28 billion PPP) of the other seven countries listed in table 4-19.

Table 4-18

Academic R&D expenditures, by country and source of funds: 1981, 1990, and 2000

(Percent)

Country and source of funds	1981	1990	2000
Canada			
Government	78.8	75.0	59.9
Other	17.1	20.0	31.2
Industry	4.1	5.0	8.9
France			
Government	97.7	92.9	91.5
Other	1.0	2.2	5.8
Industry	1.3	4.9	2.7
Germany			
Government	98.2	92.1	85.9
Other	0.0	0.0	2.5
Industry	1.8	7.9	11.6
Italy[a]			
Government	96.2	96.7	94.4
Other	1.1	0.9	0.8
Industry	2.7	2.4	4.8
Japan			
Government	57.8	51.2	50.2
Other	41.2	46.5	47.3
Industry	1.0	2.3	2.5
United Kingdom			
Government	81.3	73.5	64.7
Other	15.9	18.9	28.2
Industry	2.8	7.6	7.1
United States			
Government	74.1	66.9	65.0
Other	21.5	26.2	27.9
Industry	4.4	6.9	7.1

[a] Italian data are for 1999.

SOURCES: Organisation for Economic Co-operation and Development, Science and Technology Statistics database, 2003; and National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, VA, annual series).

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biomedical sciences for which the United States (and in particular NIH and U.S. pharmaceutical companies) is known.

Industrial Sector

Industrial firms account for the largest share of total R&D performance in each of the G-8 countries. However, the purposes to which the R&D is applied differ somewhat, depending on the overall industrial composition of each country's economy. Funding patterns for industrial R&D also differ from country to country, with respect to both domestic sources of funds as well as the relative proportion of foreign funding.

Sector Focus. The structure of a country's industrial activity can be a major determinant of the level and change in industrial R&D spending. National variations in such spending can result from differences in absolute output, industrial structure, and R&D intensity. Countries with the same size economy could have vastly different R&D expenditure levels (and R&D/GDP ratios). Differences might depend on the share of industrial output in the economy, as illustrated in figure 4-27 for the G-8 countries, South Korea, and China. Highly aggregated sector distributions can be deceiving, however, as some nations have much higher concentrations of R&D-intensive industries such as pharmaceutical manufacture as opposed to food processing. And even individual firms in the same industries can devote substantial resources to specific R&D activities in one country and to other activities in another country. Table 4-20 shows recent distributions of industrial R&D performance in the G-8 countries and South Korea, Sweden, Finland, and the European Union.[72]

The sector distribution of U.S. industrial R&D performance is among the most widespread and diverse among OECD members. The accumulated knowledge stock, well-developed S&T infrastructure, and large domestic market in the United States have enabled it to invest and become globally competitive in numerous industries rather than just a few industries or niche technologies. In 2000 no U.S. industrial sector accounted for more than the 13 percent of

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[72] Similar industrial R&D details for Israel and Iceland (which report the highest and fifth highest R&D/GDP ratios in the world, respectively) were not available from OECD harmonized databases (OECD 2002a).

Table 4-19
Shares of academic R&D expenditures, by country and S&E field: 1998 or 1999

Field	United States	Japan	Germany	Australia	South Korea	Spain	Sweden	Russia
	Billions of 1995 PPP dollars							
Total academic R&D	25.7	13.4	7.5	1.9	1.5	1.8	1.6	0.4
	Percent distribution							
Total academic R&D								
NS&E	93.7	65.6	78.4	73.0	91.6	77.9	76.3	88.3
Natural sciences	41.8	11.4	29.2	27.5	18.5	39.4	21.0	59.0
Engineering	15.5	25.0	20.3	16.1	49.1	18.7	21.9	26.7
Medical sciences	29.1	24.6	24.7	22.8	17.0	14.2	27.4	1.7
Agricultural sciences	7.4	4.6	4.2	6.6	7.0	5.6	6.1	0.9
Social sciences and humanities	6.3	34.4	20.6	27.0	8.4	22.1	17.6	11.7
Social sciences	6.3	NA	8.5	19.5	NA	14.8	11.5	6.6
Humanities	NA	NA	12.1	7.6	NA	7.3	6.1	5.1
Academic NS&E								
NS&E	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Natural sciences	44.6	17.3	37.3	37.7	20.2	50.6	27.5	66.8
Engineering	16.5	38.2	25.9	22.1	53.6	24.0	28.7	30.2
Medical sciences	31.0	37.5	31.5	31.2	18.5	18.2	35.9	1.9
Agricultural sciences	7.9	7.0	5.3	9.0	7.7	7.2	7.9	1.1

NA detail not available but included in totals
NS&E natural sciences and engineering
PPP purchasing power parity

NOTES: Percents may not sum to 100 because of rounding. Data for Australia, South Korea, and Russia are for 1998; all other data are for 1999.

SOURCES: Organisation for Economic Co-operation and Development, Science and Technology Statistics database, 2003; and Centre for Science Research and Statistics, *Russian Science and Technology at a Glance: 2000* (Moscow, 2001).

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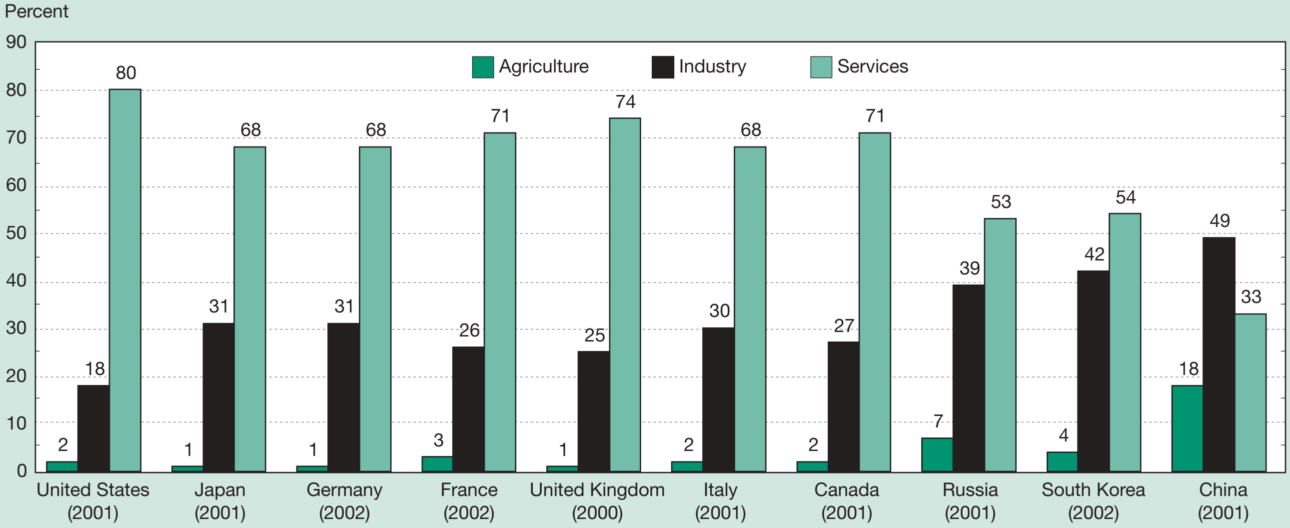
Figure 4-27
Composition of GDP for selected countries, by sector: 2000, 2001, or 2002



GDP gross domestic product

NOTES: Government purchases are included in sector shares. In 2001, government purchases represented 12.4 percent of U.S. GDP.

SOURCE: Central Intelligence Agency, *The World Fact Book 2002*, http://www.cia.gov/cia/publications/factbook/index.html.

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Table 4-20

Industrial R&D, by industry sector for selected countries: Selected years, 1997–2000

Industry	United States (2000)	Canada (2000)	Germany (2000)	France (1999)	Italy (2000)	Japan (2000)	United Kingdom (2000)	Russian Federation (1997)	South Korea (2000)	Sweden (1999)	Finland (2000)	European Union (1999)
	Billions of PPP dollars											
Total	199.5	9.0	37.4	19.2	7.4	69.7	17.8	5.7	14.1	5.9	3.1	101.7
	Percent distribution											
All business enterprise	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Manufacturing	64.9	67.3	91.3	85.7	79.9	95.0	80.2	36.8	83.7	85.4	85.0	84.3
Food, beverages, and tobacco	0.8	1.0	0.6	1.8	1.3	2.4	2.3	0.1	1.4	0.9	1.6	1.7
Textiles, fur, and leather	0.1	0.7	0.6	0.5	0.3	0.7	0.3	0.1	0.9	0.1	0.4	0.5
Wood, paper, printing, and publishing	1.6	1.3	0.4	0.4	0.3	1.1	0.3	0.2	0.4	2.4	3.5	0.7
Coke, refined petroleum products, and nuclear fuel	0.6	0.5	0.1	1.4	0.9	0.3	1.6	0.5	2.0	0.2	0.8	0.8
Chemicals (less pharmaceuticals)	4.2	1.4	10.9	6.1	5.1	8.1	5.9	1.8	4.7	1.6	2.4	NA
Pharmaceuticals	6.5	6.1	6.1	13.2	8.6	6.9	24.7	0.2	1.4	16.5	5.0	NA
Rubber and plastic products	0.8	0.4	1.7	2.8	1.8	2.4	0.5	0.3	1.4	0.7	1.9	1.7
Nonmetallic mineral products	0.4	0.1	1.2	1.3	0.3	1.6	0.4	0.2	0.5	0.2	0.6	0.9
Basic metals	0.3	1.4	0.7	1.4	0.4	2.8	0.5	1.1	1.3	2.0	1.0	1.0
Fabricated metal products	1.0	1.1	1.4	1.0	0.6	1.1	0.6	0.2	0.6	0.3	2.2	1.1
Machinery NEC	3.4	2.2	9.5	4.5	7.5	9.3	6.1	11.9	2.8	8.7	7.6	7.6
Office, accounting, and computing machinery	5.2	4.8	1.9	1.9	1.1	10.8	1.0	0.0	7.1	0.7	0.1	1.8
Electrical machinery	1.9	1.4	3.0	3.7	2.3	9.8	3.7	1.3	1.7	1.4	4.6	3.1
Electronic equipment (radio, television, and communications)	12.9	28.8	10.7	12.5	19.3	18.8	8.9	3.2	36.7	23.4	49.2	13.5
Instruments, watches, and clocks	9.6	1.3	4.9	6.7	2.9	4.5	4.2	0.8	1.0	5.7	2.7	4.6
Motor vehicles	9.3	1.9	29.6	13.4	15.4	12.4	7.5	3.2	14.3	17.0	0.4	16.1
Other transport equipment (less aerospace)	0.6	0.1	1.0	0.6	1.2	0.3	2.0	3.0	1.9	0.5	0.6	1.0
Aerospace	5.2	12.3	6.6	11.8	10.5	0.8	9.5	8.7	2.9	2.9	0.1	7.6
Furniture, other manufacturing NEC	0.4	0.6	0.5	0.8	0.2	0.9	0.2	0.0	0.8	0.2	0.3	0.5
Recycling	NA	NA	0.0	0.0	0.0	NA	0.0	0.0	0.0	NA	0.2	NA
Electricity, gas, and water	0.1	1.6	0.3	2.5	0.2	0.9	1.4	0.5	1.8	0.6	1.2	NA
Construction	0.1	0.2	0.2	0.9	0.2	1.7	0.3	0.9	3.7	0.4	1.0	NA
Agriculture and mining	NA	NA	NA	NA	NA	NA	NA	3.3	NA	NA	NA	NA
Services	34.4	29.0	7.8	9.1	19.7	2.1	16.6	58.5	10.5	12.8	12.0	13.0
Wholesale, retail trade, motor vehicle repair, etc.	12.6	7.3	NA	0.0	0.4	NA	NA	0.0	0.3	0.2	0.1	NA
Hotels and restaurants	NA	NA	NA	0.0	0.0	NA	NA	0.0	0.0	NA	NA	NA
Transport and storage	0.1	0.2	NA	3.6	0.1	0.2	NA	0.5	0.5	0.0	0.5	NA
Communications	0.7	0.9	NA	NA	0.1	NA	5.9	0.7	3.6	2.6	6.1	NA
Financial intermediation (including insurance)	2.0	1.9	NA	NA	1.2	NA	NA	0.0	0.0	NA	NA	NA
Computer and related activities	7.4	6.2	NA	2.5	2.5	1.9	5.3	1.1	3.9	4.5	3.8	3.7
Research and development	7.0	10.5	2.5	NA	12.9	NA	3.7	44.9	0.3	4.8	NA	NA
Other business activities NEC	NA	1.9	NA	3.0	2.2	NA	1.1	0.4	1.8	0.6	0.3	2.2
Community, social, and personal service activities, etc.	NA	NA	NA	NA	0.2	NA	0.1	10.9	0.2	0.0	1.2	NA

NA not available separately

NEC not elsewhere classified

PPP purchasing power parity

NOTES: Data for communications industry in United States include only telecommunications R&D. Analytical Business Enterprise Research and Development (ANBERD) data not available for Switzerland. Data are for years listed under country names.

SOURCES: Organisation for Economic Co-operation and Development (OECD), ANBERD database, 2002; and OECD, *R&D Efforts in China, Israel, and Russia: Some Comparisons With OECD Countries* (Paris, 2000).

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total industrial R&D concentrated in the electronic equipment manufacturing sector. In comparison, most of the other countries displayed somewhat higher sector concentrations. For example, 20 percent or more of industrial R&D was concentrated in electronic equipment manufacturing in Finland (at 49 percent of its industry total), South Korea (37 percent), Canada (29 percent), and Sweden (23 percent). Indeed, the electronic equipment sector was among the largest performers of industrial R&D in 7 of the 11 countries shown and was the second largest performer of industrial R&D for the entire European Union. Among other manufacturing sectors, motor vehicles in Germany and pharmaceuticals in the United Kingdom accounted for 20 percent or more of total R&D performance, which was consistent with general economic production patterns. [See OECD (2001) for a harmonized historical series on industrial R&D expenditures in several OECD countries.]

One of the more significant trends in both U.S. and international industrial R&D activity has been the growth of R&D in the service (nonmanufacturing) sector. According to the internationally harmonized data in table 4-20, this sector accounted for 34 percent of total industrial R&D performance in the United States in 2000.[73] A number of other countries also reported substantial increases in their service sector R&D expenditures during the past 25 years. Among G-7 countries, nonmanufacturing shares of total industrial R&D increased about 5 percentage points in France and Italy and 13 percentage points in the United States, United Kingdom, and Canada from the early 1980s to the late 1990s (Jankowski 2001). In each of these three English-speaking countries, computer and related services account for a substantial share of the service R&D totals. (See sidebar, "R&D in the ICT Sector.") Furthermore, the service sector appears to be an important locus of industrial R&D activity in several countries, reflecting in part the growth in outsourcing and greater reliance on contract R&D in lieu of in-house performance, as well as intramural R&D in these industries.

According to national statistics for recent years, the nonmanufacturing sector accounted for less than 10 percent of total industrial R&D performance in only three of the G-7 countries (Germany, France, and Japan). Among the countries listed in table 4-20, the service sector share ranged from as little as 2 percent in Japan to 59 percent in Russia. The latter figure, however, primarily occurred because specialized industrial research institutes perform a large portion of Russia's industrial and governmental R&D and are classified under "research and development" within the service sector. Apart from these institutes, the manufacturing-nonmanufacturing split in Russia's industrial R&D would be similar to ratios in the United States [American Association for the Advancement of Science and Centre for Science Research and Statistics (AAAS/CSRS) 2001].

Source of Funds. Most of the funding for industrial R&D in each of the G-8 countries is provided by industry itself. As is the situation for OECD countries overall, government financing accounts for a small and declining share of total industrial R&D performance within G-7 countries. (See "Government Sector.") Government financing shares ranged from as little as 2 percent of industrial R&D performance in Japan to 11 percent in Italy (appendix table 4-45). (For recent historical reasons, Russia was the exception to this pattern among the G-8 countries, with government accounting for 49 percent of its industry total.) In the United States in 2001, the Federal Government provided about 9 percent of the R&D funds used by industry, and the majority of that funding was obtained through DOD contracts.

Foreign sources of R&D funding increased in many countries between 1981 and 2001 (figure 4-28). The role of foreign funding in R&D varied from country to country, accounting for as little as 0.4 percent of industrial R&D in Japan to as much as 27 percent in Canada in recent years. This foreign funding predominantly came from foreign corporations but also included funding from foreign governments and other foreign organizations. The growth of this funding primarily reflects the increasing globalization of industrial R&D activities. For European countries, however, the growth in foreign sources of R&D funds may also reflect the expansion of coordinated European Community efforts to foster cooperative shared-cost research through its European Framework Programmes.[74] Although the growth pattern of foreign funding has seldom been smooth, it accounted for more than 20 percent of industry's domestic performance totals in Canada and the United Kingdom and almost 10 percent of industrial R&D performed in France and Russia between 1981 and 2001 (figure 4-28). Such funding takes on even greater importance in many of the smaller OECD countries as well as in less industrialized countries (OECD 1999). The recent global slowdown in industrial R&D spending may be reflected in a decline in foreign funding as a share of domestic industrial R&D in the most recent years' data for Italy, the United Kingdom, and Russia. Although data exist on foreign sources of R&D funding for other countries, there are no data on foreign funding sources of U.S. R&D performance. However, the importance of international investment for U.S. R&D is highlighted by the fact that approximately 13 percent of funds spent on industrial R&D performance

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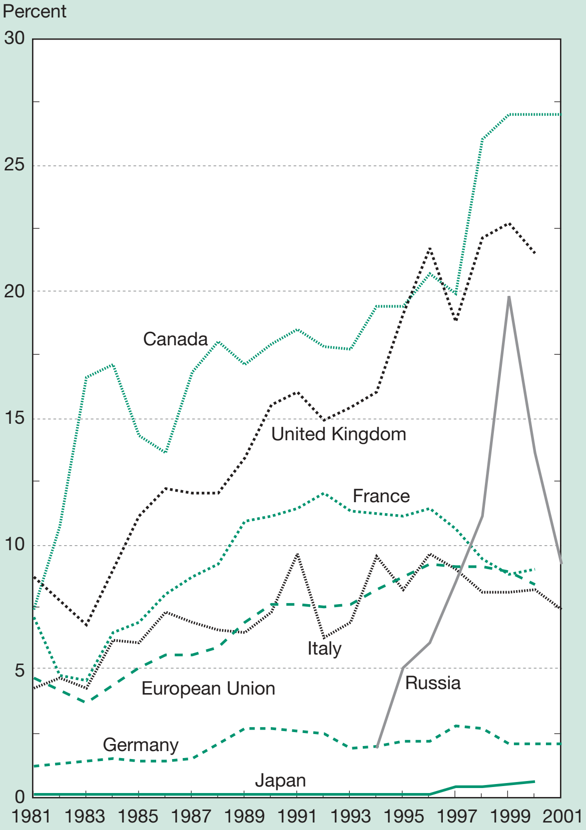
[73] As previously discussed, the recent growth in R&D in the U.S. trade industry reflects statistical procedures more than actual R&D activity in wholesale and retail trade companies.

[74] Since the mid-1980s, European Community (EC) funding of R&D has become increasingly concentrated in its multinational Framework Programmes for Research and Technological Development (RTD), which were intended to strengthen the scientific and technological bases of community industry and to encourage it to become more internationally competitive. EC funds distributed to member countries' firms and universities have grown considerably. The EC budget for RTD activities has grown steadily from 3.7 billion European Currency Units (ECU) in the First Framework Programme (1984–87) to an estimated 15 billion ECU for the Fifth Framework Programme (1998–2002). The institutional recipients of these funds tend to report the source as "foreign" or "funds from abroad." Eurostat, *Statistics on Science and Technology in Europe: Data 1985–99* (Luxembourg: European Communities, 2001).

Figure 4-28
Industrial R&D financed by foreign sources: 1981–2001



SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators,* 2002. See appendix table 4-46.

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in 2000 were estimated to have come from majority-owned affiliates of foreign firms investing domestically.[75]

Government Sector

As in the United States, in most countries the government sector performs much less R&D than it funds. And, also as in the United States, the role of the government as a performer of R&D has been shrinking internationally. The government sector accounted for 13 percent of the OECD R&D performance total as recently as 1995. This share fell to 10 percent of OECD members' combined R&D performance in 2000 (OECD 2002a) and equaled 24 percent or (usually much) less in each of the G-8 countries (appendix table 4-45).

Government R&D Funding Totals. A significant trend in the G-7 and other OECD countries has been the decline in government R&D funding relative to R&D funding from the private sector. In 2000, less than 30 percent of all R&D funds were derived from government sources, down considerably from the 44 percent share reported in 1981[76] (figure 4-29). Part of the relative decline reflects the effects of budgetary constraints, economic pressures, and changing priorities in government funding (especially the relative reduction in defense R&D in several of the major R&D-performing countries, notably France, the United Kingdom, and the United States). This trend also reflects the absolute growth in industrial R&D funding as a response to increasing international competitive pressures in the marketplace, irrespective of government R&D spending patterns. Both of these considerations are reflected in funding patterns for industrial R&D performance. In 1982, government provided 23 percent of the funds used by industry in conducting R&D within OECD countries, whereas by 2000 government's share of the industrial R&D total had fallen by almost two-thirds, to 8 percent of the total.

Government R&D Priorities. A breakdown of public expenditures by major socioeconomic objectives provides insight into government priorities that differ considerably across countries and shift over time.[77] Within OECD, the defense share of governments' R&D financing total declined annually from 44 percent in 1986 to 29 percent in 1999 (table 4-21). Much of this decline was driven by the U.S. experience: 54 percent of the U.S. Government's $98 billion R&D investment during 2002 was devoted to national defense, down from its 69 percent share in 1986.

Concurrent with the changes in overall defense/nondefense R&D shares, notable shifts occurred in the composition of OECD countries' governmental nondefense R&D support during the past 2 decades. In terms of the broad socioeconomic objectives to which government programs are classified in various international reports (OECD 2001 and 2002g), government R&D shares increased most for health and the environment and for various nondirected R&D activities (identified in table 4-21 as *other purposes*).[78] Growth in health-related R&D financing was particularly strong in the United States, whereas many of the other OECD countries reported relatively higher growth in environmental

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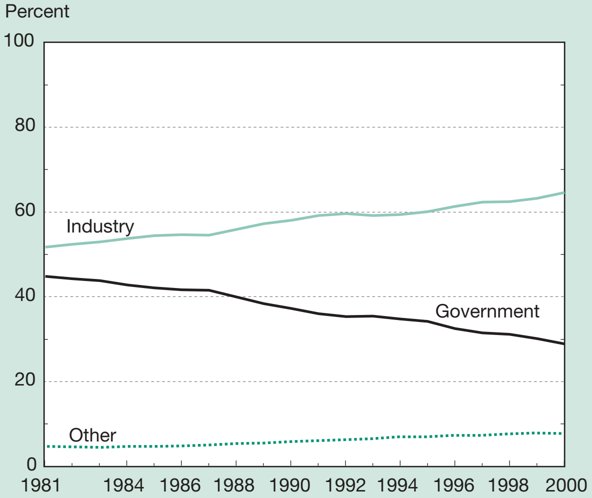
[75] The figures used here to approximate foreign involvement are derived from the estimated percentage of U.S. industrial performance undertaken by majority-owned (i.e., 50 percent or more) nonbank U.S. affiliates of foreign companies. The U.S. foreign R&D totals represent industry funding based on foreign ownership regardless of originating source, whereas the foreign totals for other countries represent flows of foreign funds from outside the country to any of its domestic performers. (See "R&D Investments by Multinational Corporations.")

[76] Among all OECD countries, the government sector accounts for the highest funding share in Portugal (63 percent of its 2000 R&D total) and the lowest share in Japan (20 percent in 2000).

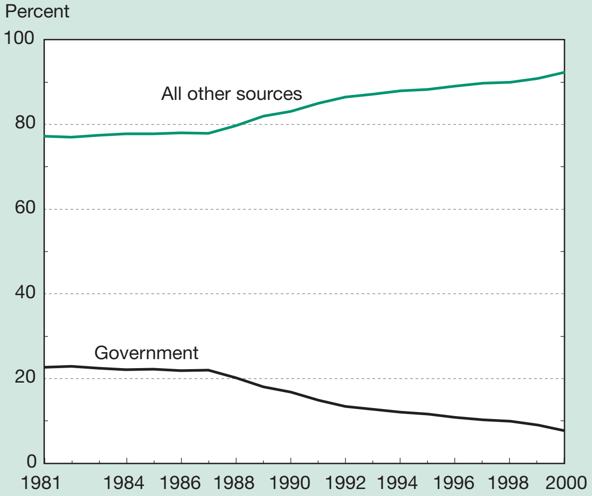
[77] Data on the socioeconomic objectives of R&D funding are generally extracted from national budgets. Because budgets already have their own methodology and terminology, these R&D funding data are subject to comparability constraints not placed on other types of international R&D data sets. Notably, although each country adheres to the same criteria for distributing their R&D by objective, as outlined in OECD's Frascati Manual (OECD 2002f), the actual classification may differ among countries because of differences in the primary objective of the various funding agents.

[78] Health and environment programs include human health, social structures and relationships, control and care of the environment, and exploration and exploitation of the Earth. R&D for *other purposes* in table 4-21 includes nonoriented research, other civil research, and research financed from GUF (e.g., the estimated R&D content of block grants to universities described in the earlier discussion of the academic sector.).

Figure 4-29
Sources of R&D expenditures in OECD countries: 1981–2000



All R&D



Industry R&D

OECD Organisation for Economic Co-operation and Development

SOURCE: OECD, *Main Science and Technology Indicators,* 2002. See appendix table 4-47.

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research programs. Indeed, as is indicated from a variety of R&D metrics, the emphasis on health-related research is much more pronounced in the United States than in other countries. In 2001 the Federal Government devoted 25 percent of its R&D investment to health-related R&D, making such activities second in priority only to defense.[79]

The relative shift in emphasizing nondirected R&D reflects government priority setting during a period of fiscal austerity and constraint. With fewer discretionary funds available to support R&D, governments have tended to conduct activities that are traditionally in the government sphere of responsibility and for which private funding is less likely to be available. For example, basic research projects are inextricably linked to higher education. [See Kaiser et al. (1999) for a description of recent efforts to make higher education R&D data more internationally comparable.] Conversely, the relative share of government R&D support for economic development programs declined considerably from 38 percent in 1981 to 23 percent in 1999. Economic development programs include the promotion of agriculture, fisheries and forestry, industry, infrastructure, and energy, all activities for which privately financed R&D is more likely to be provided without public support, although the focus of such private and public support would undoubtedly differ somewhat.

Differing R&D activities are emphasized in each country's governmental R&D support statistics.[80] As noted above, defense accounts for a relatively smaller government R&D share in most countries than in the United States. In recent years, the defense share was relatively high in the United Kingdom, Russia, and France at 46, 44, and 30 percent, respectively, but was less than 12 percent each in Germany, Italy, Canada, and Japan. South Korea expended 16 percent of its $6 billion government R&D budget on defense-related activities (figure 4-32). Japan committed 27 percent of its non-GUF governmental R&D support to energy-related activities, reflecting the country's historical concern about its high dependence on foreign sources of energy. In Canada 14 percent of the government's non-GUF R&D funding was directed toward agriculture. Space R&D received considerable support in France and Russia (13 and 10 percent, respectively), whereas industrial production and technology accounted for 15 percent or more of governmental R&D funding in Canada, Germany, Italy, and South Korea. Industrial production and technology is the leading socioeconomic objective for R&D in South Korea, accounting for 30 percent of all government R&D. This funding is primarily oriented toward the development of science-intensive industries and is aimed at increasing economic efficiency and technological development.[81] Industrial technology programs accounted for 12 percent of the Japanese total but less than 1 percent of the U.S. total (figure 4-32). The latter figure, which includes mostly R&D funding by NIST, is understated relative to most other countries as a result of data compilation differences. In part, the low U.S. industrial development share reflects the expectation that firms will finance industrial R&D

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[79] Most of the health-related R&D is classified as research, whereas about 90 percent of defense R&D is classified as development.

[80] For the purpose of cross-country comparisons, the shares reported here and in figure 4-32 have been calculated after removing research financed from general university funds (GUF). These shares thus represent government R&D funds dedicated to specific socioeconomic objectives. Shares including GUF can be found in appendix table 4-48. In 2000–2001 the GUF portion of total national governmental R&D support was 44 percent in Italy, 39 percent in Germany, 35 percent in Japan, and between 22 and 29 percent in the United Kingdom, Canada, and France. South Korea and Russia are like the United States in that they do not report GUF.

[81] Historically, Russia has also devoted a large share of government R&D to industrial development. Fully 27 percent of the government's 1998 R&D budget appropriations for economic programs were used to assist in the conversion of the country's defense industry to civil applications [American Association for the Advancement of Science and Centre for Science Research and Statistics (AAAS/CSRS) 2001].

R&D in the ICT Sector

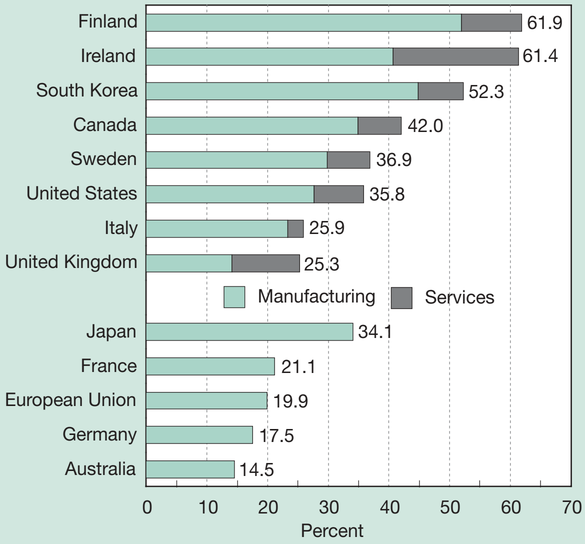
Information and communications technologies (ICTs) play an increasingly important role in the economies of OECD member countries. Both the production and use of these technologies contribute to output and productivity growth. Compared with other industries, ICT industries are among the most R&D intensive, with their products and services embodying increasingly complex technology. Because R&D data are often unavailable for detailed industries, for the purpose of this discussion ICT industries include the following ISIC (International Standard Industrial Classification) categories:

- Manufacturing industries: 30 (Office, accounting, and computer machinery), 32 (Manufacture of radio, television, and communications equipment apparatus), and 33 (Manufacture of medical, precision and optical instruments, watches, and clocks)
- Services industries: 64 (Post and communications) and 72 (Computer and related activities) (OECD 2002e)

In 1999 and 2000, the ICT sector accounted for more than a fourth of total business R&D expenditures in most OECD countries and, as shown in figure 4-30, more than half of total business R&D in Finland, Ireland, and South Korea. According to these internationally comparable tabulations, ICT industries accounted for 36 percent of the industrial R&D in the United States and 34 percent of the Japanese total. Of the large European economies, the United Kingdom comes closest to matching the ICT R&D concentration of the United States and Japan, with a particularly high concentration of ICT services R&D. For a discussion of R&D alliances in the ICT sector, see "International Technology Alliances."

Although several other OECD member countries had much higher concentrations of R&D in manufacturing ICT industries than the United States in 2000, the United States still accounted for half of all OECD-wide R&D expenditures in ICT manufacturing (figure 4-31). Japan and South Korea, which have historically emphasized ICT manufacturing, accounted for more than a fourth of the total, with the larger OECD members making up the bulk of the remainder.

Figure 4-30
Industrial R&D, by ICT sector, for selected countries: 1999 or 2000



ICT information and communications technologies

NOTES: Data for European Union, France, Sweden, and Ireland are for 1999. All other data are for 2000. ICT service-sector R&D data are not available for Japan, France, European Union, Germany, and Australia.

SOURCE: Organisation for Economic Co-operation and Development, DSTI/EAS Division, Analytical Business Enterprise Research and Development database, 2002.

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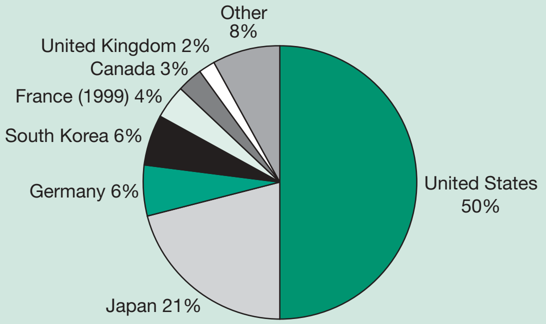
Figure 4-31
OECD-wide ICT manufacturing R&D, by selected country: 2000



ICT information and communications technologies
OECD Organisation for Economic Co-operation and Development

NOTE: Figure based on only 19 OECD countries.

SOURCE: OECD, *Measuring the Information Economy* (Paris, 2002).

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Table 4-21
Government R&D support for defense and nondefense purposes, all OECD countries: 1981–99
(Percent)

		Nondefense R&D budget shares				
Year	Defense	Total	Health and environment	Economic development programs	Civil space	Other purposes
1981	35.6	64.4	19.7	37.6	9.9	32.8
1982	38.1	61.9	19.4	37.7	8.6	34.3
1983	39.9	60.1	19.3	36.8	7.7	36.2
1984	41.8	58.2	20.1	36.0	7.9	36.0
1985	43.4	56.6	20.5	35.6	8.6	35.3
1986	44.4	55.6	20.5	34.5	8.8	36.2
1987	44.1	55.9	21.2	32.3	9.8	36.7
1988	43.4	56.6	21.6	30.7	10.2	37.6
1989	41.9	58.1	21.8	29.7	11.0	37.6
1990	39.9	60.1	22.0	28.7	11.9	37.4
1991	36.9	63.1	22.0	28.1	12.0	38.0
1992	35.6	64.4	22.1	26.9	12.1	38.9
1993	35.6	64.4	22.1	26.0	12.3	39.6
1994	33.1	66.9	22.4	25.1	12.4	40.1
1995	31.2	68.8	22.4	24.3	12.1	41.1
1996	30.9	69.1	22.6	24.2	11.9	41.3
1997	30.7	69.3	22.8	24.5	11.4	41.3
1998	30.0	70.0	23.5	22.6	11.4	42.5
1999	29.3	70.7	24.4	23.1	10.6	41.8

OECD Organisation for Economic Co-operation and Development

NOTE: Nondefense R&D classified as “other purposes” consists largely of general university funds (GUF) and nonoriented research programs.

SOURCE: OECD, Main Science and Technology Indicators database, 2002.

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activities with their own funds; in part, government R&D that may be indirectly useful to industry is often funded with other purposes in mind such as defense and space (and is therefore classified under other socioeconomic objectives).

Compared with other countries, Germany, France, and Italy invested relatively heavily in nonoriented research at 26, 25, and 24 percent, respectively, of non-GUF government R&D appropriations. The United States government invested 6 percent of its R&D budget in nonoriented research, largely through the activities of NSF and DOE.

Character of R&D Activities

Given the variations in international R&D activities by performing sector, source of funding, and industrial focus, it follows that countries would differ in terms of the character of their R&D activities. The proportion of a country’s R&D expenditures classified as basic research, applied research, or development not only reflects the sectoral structure of its national system of R&D but also indicates differences in national priorities, traditions, and incentive structures. The character of the R&D performed in a nation can change as a result of market forces and policy decisions.

R&D classification by character of work often involves a greater element of subjective assessment than other R&D indicators and hence only a third of the OECD member countries (and Russia) have reported character of work shares for 1998 or later.[82] Rather than resulting from surveys, the data are often estimated in large part by national authorities.[83] Nonetheless, where these data exist, they help differentiate the national innovation systems of different countries in terms of how their R&D resources contribute to advancing scientific knowledge and developing new technologies.

Most of the countries that report R&D character-of-work distributions emphasize development, followed by applied research and then basic research (figure 4-33). In four of the countries shown (United States, Japan, South Korea, and Russia), development accounted for at least 60 percent of national R&D, with most of the experimental development work under way in their respective industrial sectors. In all of these countries except Russia, the majority of development funding comes from the industrial sector, mirroring the U.S. pattern described earlier in this chapter. In Russia, the

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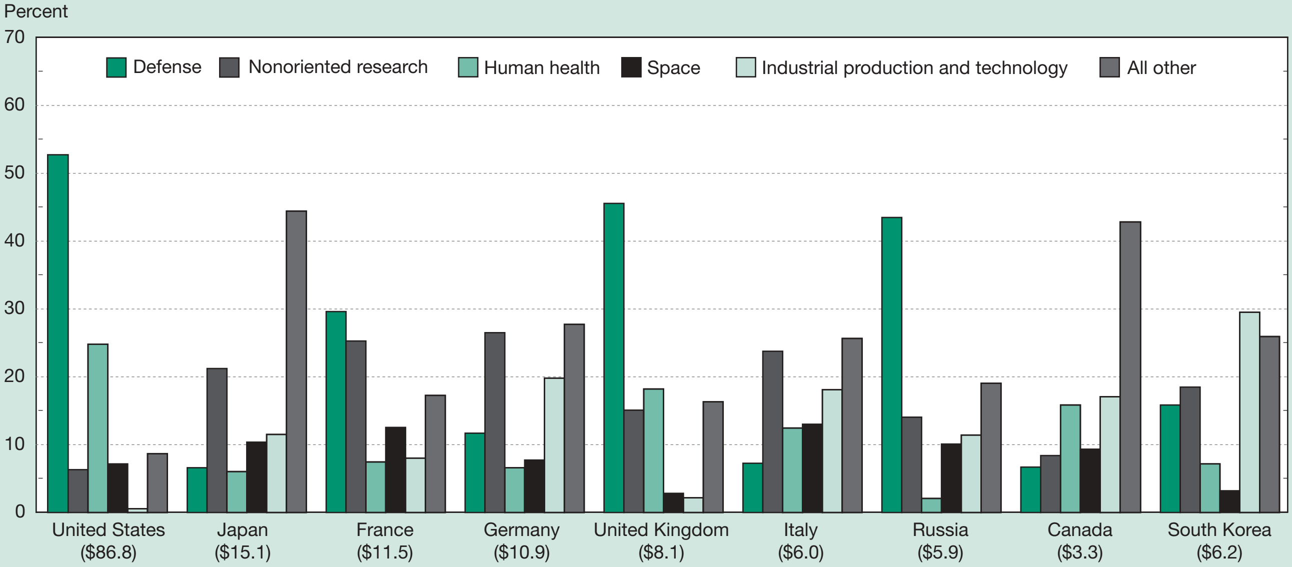
[82] For a discussion of these issues see the sidebar “Choice of the ‘Right’ R&D Taxonomy Is a Historical Concern” in *Science and Engineering Indicators 2002* [National Science Board (NSB) 2002].

[83] The magnitude of the amounts estimated as basic research also is affected by how R&D expenditures are estimated by national authorities. International R&D survey standards recommend that both capital and current expenditures be included in the R&D estimates, including amounts expended on basic research. Each of the non-U.S. countries displayed in figure 4-33 includes capital expenditures on fixed assets at the time they took place (OECD 1999). All U.S. R&D data reported in the figure include depreciation charges instead of capital expenditures. U.S. R&D plant data (not shown in the figure) are distinct from current fund expenditures for R&D.

Figure 4-32
Non-GUF government R&D support, by socioeconomic objectives, G-8 countries, and South Korea: 2000 or 2001



GUF general university funds

NOTES: Dollar amounts listed under country names represent total government R&D support less GUF in billions of U.S. purchasing power parity dollars. Data for France, United Kingdom, and Canada are for 2000; data for all other countries are for 2001. R&D is classified according to its primary government objective, although it may support any number of complementary goals. For example, defense R&D with commercial spinoffs is classified as supporting defense, not industrial development. "All other" is dominated by energy research in Japan and by agricultural production and technology research in Canada and Russia.

SOURCE: Organisation for Economic Co-operation and Development, special tabulations, 2003. See appendix table 4-48.

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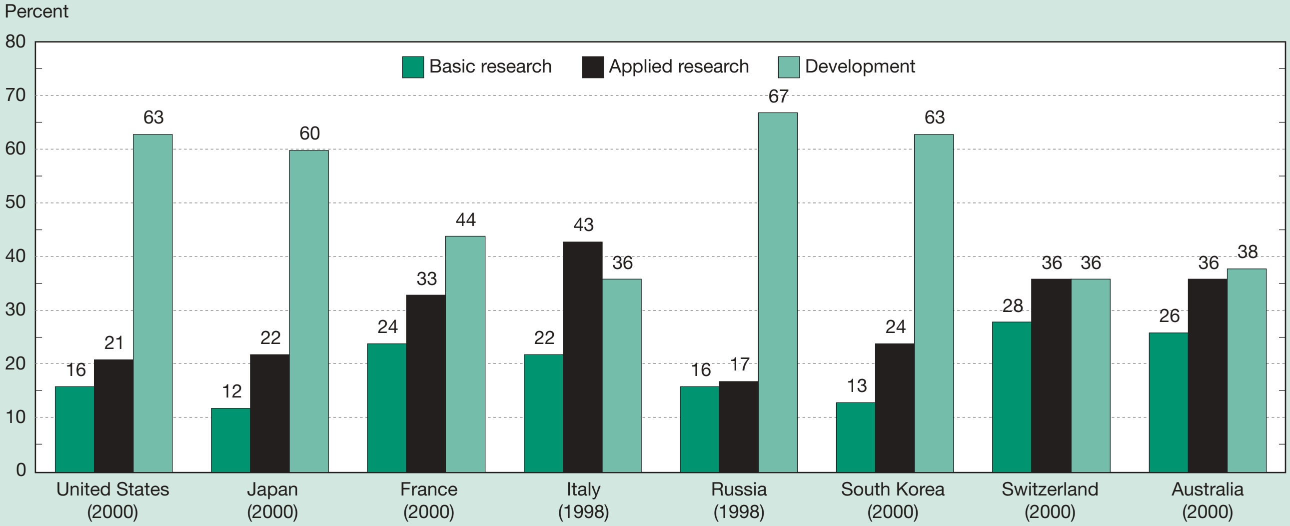
Figure 4-33
R&D expenditures of selected countries, by character of work: 1998 or 2000



NOTES: Character of work for 6 percent of Japan's R&D is unknown. Percents may not sum to 100 because of rounding.

SOURCES: Organisation for Economic Co-operation and Development, *Basic Science and Technology Statistics,* vol. 2002-1 (Paris, 2002); Centre for Science Research and Statistics, *Russian Science and Technology at a Glance 2000*, 2001; and National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, VA, annual series).

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government funds the majority of all R&D, including the R&D performed by its industrial sector. This emphasis on development was not nearly as pronounced in the other countries shown, where it ranged from 44 percent of national R&D in France to as little as 36 percent in Switzerland and Italy.

The European countries for which data are available tended to emphasize basic and applied research in lieu of development.[84] France, Italy, and Switzerland each focused more than half of their R&D expenditures on research (basic plus applied). The Czech Republic and Poland, lower-income European countries, both reported more than 30 percent of national R&D expenditures dedicated to basic research. Switzerland, a small high-income country boasting the highest number of Nobel prizes, patents, and science citations per capita worldwide, devoted more than 60 percent of its R&D to basic and applied research in 2000 despite having an industrial R&D share (74 percent) comparable to the United States and Japan. The differences among the Swiss, U.S., and Japanese character-of-work shares reflect both the high concentration of chemical and pharmaceutical R&D in Swiss industrial R&D as well as the "niche strategy" of focusing on specialty products adopted by many Swiss high-technology industries.

China, mirroring the pattern set by its dynamic neighbors Japan, Singapore, and Korea, devotes only a small fraction (5 percent) of its growing R&D effort to basic research, favoring applied R&D aimed at immediate economic development. Separate data are also available for Taiwan, where basic research accounts for 10 percent of all R&D and industry accounts for an even greater share of R&D performance (64 percent) than in China (60 percent).

R&D Promotion Policies

Many countries, regarding S&T as important both for economic growth and for general public welfare, have developed strategies for promoting domestic R&D activity, high-technology industries, and innovation. These strategies incorporate a variety of policy measures ranging from direct government spending on R&D and technology to tax policies and intellectual property policies.

Public Funding for R&D. Government spending on R&D has continued to increase at a rate faster than inflation across OECD. A number of governments have set explicit goals to increase R&D activity even further:

- Austria intends to increase its share of R&D expenditure in gross national product (GNP) to 2.5 percent by 2005.
- Canada has set a goal to raise its ranking of 15th in R&D/GDP ratio among OECD countries to 5th by 2010.
- South Korea established its first 5-year S&T plan in 1997, in which it set a goal to increase the share of the total government budget allocated to R&D to 5 percent by 2002. Although South Korea failed to achieve this goal, it increased the R&D share substantially from 3.6 percent in 1998 to 4.7 percent in 2002.
- Norway intends to raise its absolute level of R&D funding to the OECD average by 2005.
- Spain aims to increase its R&D spending as a share of GNP to 1.29 percent by 2003, up from 0.9 percent in 1990.
- The European Council has set a goal for the European Union as a region to devote 3 percent of GDP, on average, to R&D by 2010 (OECD 2002g).

R&D Tax Policies. In many OECD countries, the government not only provides direct financial support for R&D activities but also uses indirect mechanisms such as tax relief to promote national investment in S&T. Indeed, tax treatment of R&D is broadly similar among OECD countries, with some variations in the use of R&D tax credits (OECD 1996 and 2002g). The two main features of the R&D tax instruments are:

- An allowance for the deduction of industrial R&D expenditures from taxable income in the year they are incurred (exists in almost all OECD countries, including the United States)
- An additional R&D tax credit or incentive, with a rising trend in the use of incremental credits (exists in about half of OECD countries, including the United States). Incremental credits provide additional incentives for firms to increase their R&D spending over past levels. (See "Federal R&D Tax Credit.")

In addition, several OECD countries have special provisions that favor R&D in small and medium-size enterprises (SMEs). In recent years, some OECD countries have made significant changes to their R&D tax policies in an attempt to further encourage private investment in R&D:

- In 2002 Norway introduced a tax plan offering SMEs a 20 percent tax allowance for both internal and external R&D expenditures.
- The United Kingdom enacted a tax plan in 2000 that allows SMEs to deduct 150 percent of R&D expenditures.
- Australia has enhanced its R&D tax incentives, which now allow firms to deduct 125 percent of all R&D expenditures and 175 percent of the labor-cost component of incremental increases in R&D.
- Spain recently enacted a 10 percent increase in the deduction of R&D investments and broadened the scope of the incentive to include capital investments related to innovation and the costs of acquiring technology in the form of patents or licenses in addition to R&D investments (OECD 2002g).

A growing number of R&D tax incentives are being offered in OECD countries, including the United States, at the subnational (provincial and state) levels. See Poterba (1997)

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[84] The most current character-of-work data available from OECD sources for Germany are for 1993. The United Kingdom compiles this type of data only for the industry and government sectors, not for higher education or its nonprofit sector, the traditional locus of basic research activities.

for a discussion of international elements of corporate R&D tax policies.

Intellectual Property Policy and Technology Transfer. The large increase in patenting at U.S. universities and colleges following the passage of the Bayh-Dole Act in 1980 has led several OECD countries to review or modify their own policies regarding ownership of technology developed with public funding. OECD notes that one of the main impacts of these policies has been "to raise awareness of and support for technology transfer, especially within the hierarchy of PROs [publicly financed research organizations] and among researchers and graduate students" (OECD 2002g, p. 182). For more information about trends in patenting at U.S. colleges and universities, see chapter 5.

R&D Investments by Multinational Corporations

International R&D investments by multinational corporations (MNCs), such as overseas R&D spending and R&D joint ventures and alliances, support long-term activities aimed at the development of new products and technological capabilities. The resulting technological linkages across firms and geographic regions are increasingly vital in the fast-paced environment of scientific research and global market competition. International R&D spending links are particularly strong between U.S. and European pharmaceuticals, computers, and transportation equipment companies.[85] In recent years, the United States has attracted large investments by foreign R&D-performing companies. Foreign-owned R&D in the United States grew at a real average annual rate of 10.8 percent from 1994 to 2000, mostly as a result of mergers and acquisitions, compared with an average annual growth rate of 6.9 percent for U.S.-owned R&D overseas. This section analyzes data on foreign direct investment (FDI) in R&D (see sidebar, "Foreign Direct Investment in R&D"), including activity by foreign-owned companies in the United States, parent companies of U.S. MNCs, and U.S. overseas affiliates in terms of investing or host countries, their industrial focus, and implications for the ownership structure of U.S. R&D. Major findings were:

- Foreign-owned firms conducting R&D in the United States accounted for $26.1 billion (13 percent) of the $199.5 billion in total industrial R&D expenditures in the United States in 2000. This share fluctuated between 11 and 13 percent during the period 1994–2000.
- In 2000 about two-thirds of foreign-owned R&D in the United States was performed in three industries: chemicals and pharmaceuticals, computer and electronic products, and transportation equipment. Seven countries invested $1 billion or more in R&D in the United States in 2000: Germany, the United Kingdom, Switzerland, Japan, Canada, France, and the Netherlands, accounting

Foreign Direct Investment in R&D

Statistics on overseas R&D activity by U.S. companies or by foreign-owned companies in the United States are part of operations data associated with U.S. direct investment abroad (USDIA) and foreign direct investment in the United States (FDIUS), respectively. The term foreign direct investment (FDI) is used below and throughout this section to refer to either type of direct investment. Direct investment refers to the ownership of productive assets outside the home country by multinational corporations (MNCs). More specifically, the U.S. Bureau of Economic Analysis (BEA) defines direct investment as ownership or control of 10 percent or more of the voting securities of a business in another country. FDI can be examined using either direct investment position and related capital inflows/outflows data (balance of payments method) or economic activities of foreign affiliates of MNCs (financial and operations data). This section uses the latter set of indicators, including gross product, sales, employment, and R&D expenditures, to analyze *majority-owned* affiliates (those in which the ownership stake of parent companies is more than 50 percent).

Most FDI involves overseas production, marketing, and distribution, not R&D-oriented activities. Increasingly, however, companies have been expanding knowledge-based technology development activities abroad in search of synergies and location-specific expertise. Other incentives include R&D costs considerations and the support of foreign production sites (Kumar 2001; and Niosi 1999). The incentives, goals, and character of overseas R&D activities can be summarized in two broad categories: (1) *market seeking,* or *home-base exploiting,* supporting the development of new markets and foreign production sites, and (2) *asset-seeking,* or *home-base augmenting,* pursuing science-based technologies and capabilities (Bas and Sierra 2002; Kuemmerle 1999; and von Zedtwitz and Gassmann 2002). In the first category, MNCs aim to use and profit from proprietary knowledge overseas by transferring and adapting technologies for local markets, emphasizing product development expenditures. The second category targets the development of long-term innovative capabilities by taking advantage of novel or complementary knowledge located elsewhere. The latter is a more recent development within the internationalization of R&D activities, driven by the demands of knowledge-based competition, particularly among OECD countries (Niosi 1999).

The tradeoffs and complementarities between these two broad objectives affect not only the relative emphasis of research versus development activities in technology-intensive MNCs but also location and organizational decisions (e.g., proximity to production and/or research clusters, stand-alone R&D facilities, contractual alliances), financing mechanisms (e.g., parent-company funding, venture capital, government grants), and technical personnel needs.

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[85] Much like trends in international technology alliances discussed earlier in this chapter.

for about 90 percent of all R&D expenditures by foreign-owned firms in the United States.

- Parent companies of U.S. MNCs accounted for two-thirds of the R&D spending by all industrial R&D performers in the United States in 2000. In that year, these parent companies had R&D expenditures of $131.6 billion in the United States, whereas their majority-owned foreign affiliates (MOFAs) had R&D expenditures of $19.8 billion for a total of $151.3 billion in global R&D expenditures.
- Two-thirds of the R&D performed overseas in 2000 by U.S.-owned companies ($13.2 billion of $19.8 billion) took place in six countries: the United Kingdom, Germany, Canada, Japan, France, and Sweden. At the same time, emerging markets such as Singapore, Israel, Ireland, and China were increasingly attracting R&D activities by U.S. subsidiaries. In 2000, each of these emerging markets reached U.S.-owned R&D expenditures of $500 million or more, levels considerably higher than those in 1994.
- Three manufacturing sectors dominated overseas R&D activity by U.S.-owned companies: transportation equipment, computer and electronic products, and chemicals and pharmaceuticals. These are the same three industries that accounted for most foreign-owned R&D in the United States, implying a high degree of R&D globalization in these industries.

Foreign-Owned R&D Spending in the United States

Overview

The economic presence of foreign-owned companies in the United States is substantial. In 2000, majority-owned U.S. affiliates of foreign companies—affiliates operating in the United States in which the ownership stake of foreign direct investors is more than 50 percent—had a gross product (value added) of $449.4 billion, sales of $2.1 trillion, and almost 5.6 million employees in the United States, according to data from the U.S. Bureau of Economic Analysis (BEA)[86] (table 4-22). These affiliates accounted for 6.0 percent of U.S. private-industry GDP and 4.9 percent of U.S. private employment in 2000 (Zeile 2002).

R&D spending by majority-owned U.S. affiliates of foreign companies (hereafter, *foreign-owned R&D*) reached $26.1 billion in 2000, an increase of 8.6 percent over 1999 expenditures.[87] In 2000, foreign-owned R&D spending accounted for 13 percent of the $199.5 billion in total industrial R&D expenditures in the United States, according to NSF's Survey of Industrial Research and Development.[88] This share fluctuated between 11 and 13 percent between 1994 and 2000. Note that the share of foreign-owned R&D spending in 2000 (13 percent) was more than twice the comparable share of U.S. private-industry gross product and employment, reflecting significant activity in R&D-intensive industries.

Investing Country and Industry Analysis

Relatively few investing countries account for most of the foreign-owned R&D in the United States. In 2000, European-owned subsidiaries accounted for $18.6 billion (71 percent) of foreign-owned R&D in the United States (figure 4-34), a share comparable with their 67 percent share in foreign-owned gross product in the United States. The corresponding R&D shares for Canadian- and Asia/Pacific-owned subsidiaries were 14.0 and 10.9 percent, respectively. In particular, R&D activities by U.S. affiliates of foreign companies were dominated by seven investing countries with $1 billion or more in R&D expenditures (table 4-22). These top countries accounted for about 90 percent of all foreign-owned R&D in the United States, a somewhat higher percentage than their corresponding shares of gross product (value added), sales, and employment (82, 73, and 80 percent, respectively). German- and British-owned subsidiaries accounted for about 20 percent each of the total foreign-owned R&D spending in the United States in 2000, followed by Canadian-owned affiliates with 14 percent. Relative to gross product, German-, Canadian-, and Swiss-owned companies, respectively, were the most R&D-intensive subsidiaries (table 4-22).

Foreign-owned R&D in the United States is performed primarily in manufacturing. In 2000 about two-thirds was performed in three industries: 27 percent in chemicals (of which 80 percent was in pharmaceuticals), 24 percent in computer and electronic products (of which three-fourths was in communications equipment), and 12 percent in transportation equipment, mostly in motor vehicles. Electrical equipment and components and machinery accounted for 7 and 3 percent, respectively, of foreign-owned R&D in the United States (table 4-23 and appendix table 4-50). The information sector and the professional, technical, and scientific services sector each represented 3 percent of this U.S. total in 2000, exhibiting little change from 1999.

Firms from some investing countries are particularly active in certain industries. In 2000, 80 percent of R&D performed by Swiss-owned subsidiaries in the United States was performed by chemical and pharmaceutical affiliates, compared with 38 and 24 percent, respectively, for British- and German-owned subsidiaries (table 4-23). In contrast, more than a fourth of Japanese-owned R&D was performed by companies classified in computer and electronic products.[89]

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[86] U.S. Bureau of Economic Analysis (BEA), Survey of Foreign Direct Investment in the United States, 2000. Available at http://www.bea.gov/bea/di/di1fdiop.htm. BEA data used in this section exclude data for depository institutions. All data are on a fiscal year basis. Estimates for 2000 are preliminary. For the methodology of BEA's Survey of Foreign Direct Investment in the United States, see http://www.bea.gov/bea/di/fddscrpt.htm.

[87] R&D spending data in this section are based on R&D *performance,* which refers to R&D spending according to who conducts the R&D activity, whether for the performer itself or for others, regardless of funding source.

[88] National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2003. Available at http://www.nsf.gov/sbe/srs/indus/start.htm.

[89] Further industry-country analysis is precluded by disclosure limitations.

Table 4-22
Selected operating data for majority-owned U.S. affiliates of foreign companies: 2000

Investing country	Gross product (billions of current U.S. dollars)	Sales (billions of current U.S. dollars)	Employment (millions of employees)	R&D spending (billions of current U.S. dollars)	Investing country share of R&D spending (percent)	R&D/gross product ratio (percent)
All countries	449.4	2,053.0	5.56	26.1	100.0	5.8
Top seven countries	368.2	1,492.8	4.46	23.4	89.8	6.4
Germany	54.0	308.2	0.69	5.6	21.5	10.4
United Kingdom	100.1	331.2	1.10	5.0	19.2	5.0
Switzerland	34.0	120.0	0.46	3.0	11.5	8.9
Japan	62.2	429.7	0.70	2.6	10.0	4.2
Canada	36.3	159.3	0.56	3.7	14.0	10.1
France	38.9	144.4	0.40	2.1	8.2	5.5
Netherlands	42.6	D	0.55	1.4	5.2	3.2

D data withheld to avoid disclosing operations of individual companies

NOTE: Majority-owned U.S. affiliates of foreign companies are affiliates in the United States owned more than 50 percent by foreign direct investors.

SOURCE: U.S. Bureau of Economic Analysis, U.S. Department of Commerce, Survey of Foreign Direct Investment in the United States, annual series, http://www.bea.gov/bea/di/di1fdiop.htm.

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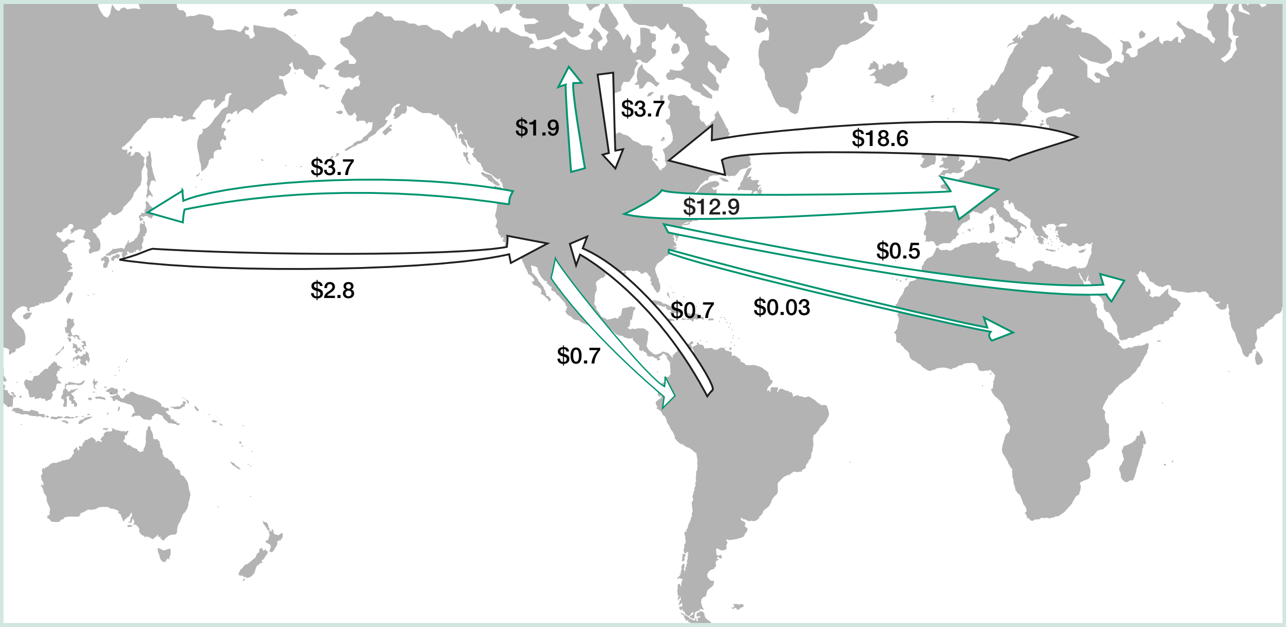
Figure 4-34
Foreign-owned R&D in United States and U.S.-owned R&D overseas, by investing/host region: 2000
(Billions of current U.S. dollars)



SOURCES: U.S. Bureau of Economic Analysis, *Foreign Direct Investment in the United States*, annual series; and U.S. Bureau of Economic Analysis, *U.S. Direct Investment Abroad,* annual series. See appendix tables 4-49 and 4-51.

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The shares of computer and electronic products as well as transportation equipment in foreign-owned R&D spending are comparable with their shares in total company-funded industrial R&D spending in the United States, according to data from NSF's Survey of Industrial Research and Development.[90] However, the share of chemicals in foreign-owned R&D was more than twice the share of chemicals in overall industrial R&D in the United States (11 percent in 2000).[91] This difference suggests the appeal of the United States as a center for chemicals and pharmaceuticals R&D for major foreign

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[90] National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2003. Available at http://www.nsf.gov/sbe/srs/indus/start.htm.

[91] National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2003. Available at http://www.nsf.gov/sbe/srs/indus/start.htm.

Table 4-23
R&D performed by majority-owned affiliates of foreign companies in United States, by selected NAICS industry of affiliate and region/country: 2000
(Millions of current U.S. dollars)

		Manufacturing						Nonmanufacturing	
Region/country	All industries	Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment	Trans-portation equipment	Information	Professional, technical, scientific services
All countries	26,089	20,554	7,023	868	6,182	1,714	3,206	790	818
Canada	3,664	D	D	5	D	D	66	D	72
Europe	18,610	15,025	6,645	D	D	1,305	3,028	D	188
France	2,135	1,750	416	30	D	D	101	D	50
Germany	5,610	5,273	1,347	139	D	D	D	D	3
Netherlands	1,366	1,303	419	3	D	2	D	0	D
Switzerland	3,013	2,702	2,391	46	34	D	0	D	D
United Kingdom	5,018	3,279	1,888	D	D	78	221	319	41
Asia and Pacific	2,840	1,463	315	D	738	21	102	4	556
Japan	2,617	1,383	D	74	706	10	102	4	555
Latin America and other Western Hemisphere	735	478	—	0	39	D	D	0	0
Africa	D	D	0	0	0	0	0	D	0
Middle East	D	88	40	0	43	0	0	D	—

— less than $500,000

D data withheld to avoid disclosing operations of individual companies

NAICS North American Industry Classification System

NOTES: Data are preliminary 2000 estimates for majority-owned (more than 50 percent) nonbank affiliates of nonbank U.S. parents by country of ultimate beneficial owner and industry of affiliate. Data include expenditures for R&D conducted by foreign affiliates, whether for themselves or for others under contract. Data exclude expenditures for R&D conducted by others for affiliates under contract.

SOURCE: U.S. Bureau of Economic Analysis, U.S. Department of Commerce, Survey of Foreign Direct Investment in the United States, annual series, http://www.bea.gov/bea/di/di1fdiop.htm. See appendix tables 4-49 and 4-50.

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companies, reflecting asset-seeking FDI goals. At the same time, the share of the gross product of these foreign-owned chemical affiliates in total foreign-owned gross product in the United States (9.1 percent) was much higher than the overall chemical industry share in U.S. (private industry) GDP in 2000 (2.1 percent), indicating substantial production activity by these affiliates (U.S. BEA 2003). These observations suggest that R&D investments by foreign chemical companies in the United States are likely pursuing both market- and asset-seeking objectives.

U.S. MNCs and Overseas R&D Spending

Overview

The economic reach of *U.S. MNCs*—defined as U.S. parent companies and their foreign affiliates—is considerable.[92] According to BEA data, U.S. MNCs had a gross product of $2.70 trillion, sales of $9.03 trillion, and 31.20 million employees worldwide in 2000 (table 4-24). Parent companies of U.S. MNCs (hereafter, *U.S. MNC-parent companies*) had R&D expenditures of $131.6 billion in 2000, whereas their MOFAs had R&D expenditures (hereafter, *U.S.-owned overseas R&D*) of $19.8 billion for a total of $151.3 billion in global R&D expenditures.[93]

Between 1994 and 2000, R&D spending by MOFAs grew at a faster rate (6.9 percent real average annual rate) than that of their U.S. parents (4.3 percent).[94] The percentage of total R&D spending by U.S. MNCs that was performed abroad by their MOFAs increased from 11.5 percent in 1994 to 13.1 percent in 2000. However, the 2000 R&D spending share of MOFAs within the worldwide operations of U.S.

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[92] BEA defines *parent company* of a U.S. multinational corporation (MNC) as an entity (individual, branch, partnership, or corporation), resident in the United States, that owns or controls at least 10 percent of the voting securities, or equivalent, of a foreign business enterprise [R. J. Mataloni, Jr., U.S. multinational companies: Operations in 2000, *Survey of Current Business* (December 2002): 111–131]. This section is based on data for U.S. nonbank MNC-parent companies and their majority-owned nonbank foreign affiliates.

[93] According to the NSF Survey of Industrial Research and Development, R&D abroad reached $17.9 billion in 2001, up 2.3 percent from $17.5 billion in 2000 (appendix tables 4-54 and 4-55). Note, however, that the 2000 estimate for R&D abroad reported in the NSF survey differs from that reported in BEA's Survey of Direct Investment Abroad because of methodological differences in the surveys. For more information, see the NSF website at http://www.nsf.gov/sbe/srs/sird/start.htm and the BEA website at http://www.bea.gov/bea/di/usdscrpt.htm.

[94] See appendix tables 4-51, 4-52, and 4-53 for historical data and selected industry detail for R&D performed by U.S. MNCs. In this section, data for R&D expenditures of U.S. MNC-parent companies include R&D performed for the Federal Government.

Table 4-24
Selected data for U.S. multinational corporation parent companies and their MOFAs: 2000

Parent companies and MOFAs	Gross product		Sales		R&D spending		Employees	
	Billions of current dollars	Percent distribution	Billions of current dollars	Percent distribution	Billions of current dollars	Percent distribution	Millions	Percent distribution
Total	2,695.3	100	9,033.9	100	151.3	100	31.2	100
U.S. parents	2,089.4	78	6,547.1	72	131.6	87	23.2	74
MOFAs	605.9	22	2,486.9	28	19.8	13	8.1	26

MOFA majority-owned foreign affiliate of U.S. parent company

NOTES: Details may not sum to totals because of rounding. MOFAs are affiliates in which combined ownership of all U.S. parents is more than 50 percent.

SOURCE: U.S. Bureau of Economic Analysis, U.S. Department of Commerce, Survey of U.S. Direct Investment Abroad, annual series, http://www.bea.gov/bea/di/di1usdop.htm.

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MNCs was approximately half of their share in employment and sales and a little more than half of their share in gross product (value added) (table 4-24). This shows a relative preference by parents of U.S. MNCs for domestically based R&D performance compared with other activities, which is consistent with the behavior of MNCs based in other advanced economies (Niosi 1999). The high concentration of R&D expenditures by U.S. MNCs at home results in a significant role of these parent companies as R&D performers in the United States. U.S. MNC-parent companies accounted for two-thirds of the R&D spending by all industrial R&D performers in the United States in 2000.[95] In comparison, the gross product of U.S. MNC-parent companies accounted for about a fifth of U.S. (private industry) GDP in 2000, according to BEA.[96]

Host Country and Industry Analysis

Two-thirds of the R&D performed overseas in 2000 by MOFAs of U.S. companies ($13.2 billion of $19.8 billion) took place in six countries: the United Kingdom, Germany, Canada, Japan, France, and Sweden (table 4-25).[97] On a regional basis, the European region accounted for approximately two-thirds ($12.9 billion) of all U.S-owned overseas R&D; the Asia/Pacific region ($3.7 billion, or 18.9 percent) outpaced Canada ($1.9 billion, or 9.5 percent) as a locale for U.S.-owned overseas R&D (figure 4-34).

In 2000, approximately three-fourths of U.S.-owned overseas R&D was performed in three manufacturing sectors: transportation equipment ($5.7 billion, or 29 percent), computer and electronic products ($4.9 billion, or 25 percent), and chemicals ($4.3 billion, or 22 percent, most of which, 83 percent, was in pharmaceuticals)[98] (table 4-25). Compared with 1999, the share of computer and electronic products increased 3 basis points, mostly at the expense of chemicals, whereas the transportation equipment share was little changed. Information as well as professional, technical, and scientific services represented 2 and 6 percent, respectively, of overseas R&D in 2000, compared with 1 and 5 percent, respectively, in 1999. Certain emerging markets play an increasing role in U.S.-owned overseas R&D. The 10 locations shown in table 4-26 hosted $3.5 billion (18 percent) in R&D expenditures by MOFAs of U.S. parent companies in 2000, compared with $1.3 billion (11 percent) in 1994. Furthermore, U.S.-owned R&D expenditures in these 10 countries increased by 15.9 percent annually (real average annual growth) from 1994 to 2000, compared with 6.9 percent annual growth for the aggregate of all host countries. For some of these locations, the real average annual increases were much higher, albeit from smaller levels of R&D activity.

The change in the relative overseas R&D rankings of these emerging markets are significant, indicating a selective diffusion of global R&D activities beyond traditional areas, likely aimed at adapting products to local markets and regulations, complemented by local know-how and human R&D resources. For example, U.S. subsidiaries in Singapore, Israel, Ireland, Taiwan, and South Korea with activities in computer and electronic product manufacturing spent a total of $1.2 billion in R&D in 2000, or 25 percent of $4.9 billion of U.S.-owned overseas R&D in this industry. A third of the combined $555 million in R&D expenditures by U.S. subsidiaries in Mexico and Brazil was devoted to transportation equipment R&D.

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[95] Note, however, that BEA's definition of U.S. MNC-parent companies does not rule out parent companies that are owned by foreign companies. About 13 percent of the published R&D expenditures for U.S. MNC-parent companies were also part of the R&D expenditures of majority-owned affiliates of foreign companies in the U.S. in 2000, and in 1999, according to BEA estimates.

[96] Ned Howenstine, Chief, Research Branch, International Investment Division, U.S. BEA, personal communication with author, 8 April 2003. To match the industrial basis for foreign direct investment statistics, GDP data used in this comparison refer to U.S. private GDP excluding depository institutions and private households.

[97] Data for U.S.-owned R&D in the United Kingdom are for 1999; most 2000 data were unavailable because of disclosure limitations.

[98] Note that these are the same three industries that accounted for most foreign-owned R&D in the United States, implying a high degree of R&D internationalization in these industries.

Table 4-25
R&D performed overseas by majority-owned foreign affiliates of U.S. parent companies, by selected NAICS industry of affiliate and region/country: 2000
(Millions of current U.S. dollars)

				Manufacturing				Nonmanufacturing	
Region/country	All industries	Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment	Trans-portation equipment	Information	Professional, technical, scientific services
All countries	19,758	17,822	4,254	764	4,878	331	5,744	383	919
Canada	1,874	1,735	272	13	194	18	1,086	3	30
Europe	12,938	11,699	3,152	509	2,085	250	4,264	255	589
France	1,445	1,356	726	57	225	14	153	1	21
Germany	3,105	3,067	235	159	460	126	1,852	2	2
Sweden	1,335	1,230	D	23	D	D	D	D	D
United Kingdom[a]	4,000	3,250	1,092	147	512	6	1,128	19	582
Asia and Pacific	3,727	3,478	684	204	2,174	D	187	105	D
Japan	1,433	1,277	560	152	450	15	19	D	D
Latin America and other Western Hemisphere	665	561	125	29	114	D	207	D	69
Africa	27	24	20	2	0	0	1	—	0
Middle East	527	324	1	8	312	0	0	D	D

— less than $500,000
D data withheld to avoid disclosing operations of individual companies
NAICS North American Industry Classification System

[a] Data are for 1999. Data for all countries include unpublished 2000 data rather than the 1999 data.

NOTES: Data are preliminary 2000 estimates for majority-owned (more than 50 percent) nonbank affiliates of nonbank U.S. parents by country of ultimate beneficial owner and industry of affiliate. Data include expenditures for R&D conducted by foreign affiliates, whether for themselves or for others under contract. Data exclude expenditures for R&D conducted by others for affiliates under contract.

SOURCE: U.S. Bureau of Economic Analysis, U.S. Department of Commerce, Survey of U.S. Direct Investment Abroad, annual series, http://www.bea.gov/bea/di/di1usdop.htm. See appendix table 4-51.

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Table 4-26
R&D performed overseas by majority-owned foreign affiliates of U.S. companies in selected economies: 1994 and 2000
(Millions of current U.S. dollars)

	1994		2000	
Location	Rank	R&D	Rank	R&D
Singapore	14	167	8	548
Israel	16	96	9	527
Ireland	8	396	10	518
China	30	7	11	506
Hong Kong	19	51	14	341
Mexico	13	183	16	305
Brazil	10	238	17	250
Malaysia	20	27	19	214
Taiwan	15	110	21	143
South Korea	26	17	22	131

NOTE: Rank refers to the relative position of the host country in terms of the amount of U.S.-owned R&D expenditures.

SOURCE: U.S. Bureau of Economic Analysis, U.S. Department of Commerce, Survey of U.S. Direct Investment Abroad, annual series, http://www.bea.gov/bea/di/di1usdop.htm.

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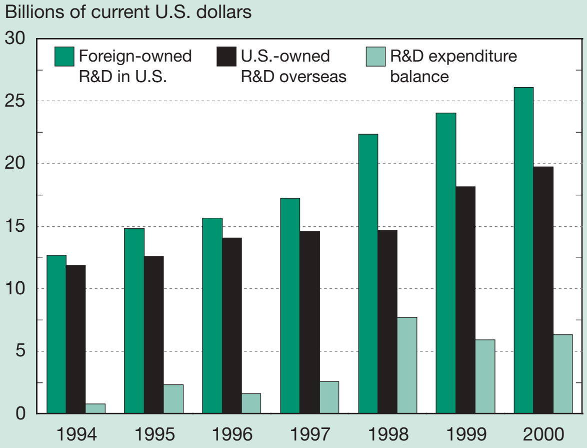
R&D Expenditure Balance

Foreign-owned R&D expenditures in the United States grew at a real average annual rate of 10.8 percent from 1994 to 2000, compared with an average annual growth rate of 6.9 percent for U.S.-owned overseas R&D. In 1998–2000 annual foreign-owned R&D spending in the United States exceeded U.S.-owned overseas R&D spending by at least $5 billion (figure 4-35), or more than 3 percent of total industrial R&D in the United States. In 2000 the difference, or expenditure balance, was $6.3 billion, down from a record $7.7 billion in 1998. At the regional level, R&D expenditures by European-owned companies in the United States outpaced overseas R&D spending by U.S. subsidiaries in Europe by $5.7 billion in 2000 (figure 4-34).

U.S.-owned companies in the United States and abroad, and foreign-owned affiliates in the United States, may have a combination of local and foreign sources of R&D funding. However, data on international funding sources for industrial R&D in the United States are generally unavailable. Both dimensions, ownership structure and funding sources, and how they may affect each other, are necessary for a fuller characterization of the international character of U.S. R&D activities. The Bureau of the Census, which conducts

Figure 4-35

Foreign-owned R&D in United States, U.S.-owned R&D overseas, and R&D expenditure balance: 1994–2000



NOTE: R&D expenditure balance equals foreign-owned R&D in the United States minus U.S.-owned R&D overseas.

SOURCES: U.S. Bureau of Economic Analysis, *Foreign Direct Investment in the United States,* annual series; and U.S. Bureau of Economic Analysis, *U.S. Direct Investment Abroad,* annual series. See appendix tables 4-49 and 4-51.

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the NSF Survey of Industrial Research and Development, and BEA, which conducts the FDI surveys, are engaged in a data-linking project aimed at a more detailed profile of U.S R&D performance and funding.

Conclusion

The resurgence in R&D investment in the United States from 1994 to 2000 slowed almost entirely by 2002. An uncertain economy rocked by turbulence in financial markets and terrorism led to reduced output in both the manufacturing and service sectors as well as subsequent slowdowns in R&D expenditures in many sectors. At the same time, the Federal Government's role grew in terms of both R&D funding and performance, reversing the decade-long divergence of private and public funding of R&D.

Recent acts of terrorism and military mobilizations have reversed a declining trend in the U.S. Government's share of defense-related R&D. Other countries throughout the world have maintained their focus on nondefense R&D and have attempted to take proactive steps toward intensifying and focusing their national R&D activity. These steps range from increasing general government spending to fostering high-technology industrial clusters.

The locus of R&D activities is also shifting as a reflection of broad technological changes and new scientific research opportunities. Industrial R&D is increasingly undertaken in service (versus manufacturing) industries, and much of the industrial R&D growth has occurred in biotechnology and IT. Moreover, Federal research funds have shifted markedly toward the life sciences during the past several years.

In addition to R&D performance and funding, the organization of R&D activities also has undergone substantial change. At the corporate level, R&D activities are increasingly globally driven by the need to support or develop markets and foreign production sites and the need for science-based technologies. A parallel trend is the increasing reliance on external technology sources and R&D alliances to share costs, risks, and resources and promote the development of innovative capabilities, increasingly relevant for long-term competitiveness.

These issues not only affect the performance and policy implications of R&D activity in the United States and overseas but also present new challenges for the development of S&T indicators (National Research Council 2000). In part to address these challenges, NSF, through the Bureau of the Census, which conducts the NSF Survey of Industrial Research and Development, and BEA, which conducts the international investment surveys, have initiated a statistical linking project to further explore the international composition of R&D activity in the United States. Fuller investigations and tracking of the apparent growth in the web of partnerships among firms, universities, and Federal agencies and laboratories in conducting R&D are warranted. An understanding of this dynamic and changing scenario is essential in a U.S. economy increasingly driven by the production, diffusion, and exploitation of science-based knowledge.

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Highlights

Financial Resources for Academic R&D

- **In 2002, U.S. academic institutions spent $33 billion (in constant dollars) on research and development.** The Federal Government provided $19.0 billion, academic institutions $6.7 billion, state and local governments $2.2 billion, industry $2.1 billion, and other sources $2.4 billion.
- **Over the past 3 decades (1972 to 2002), average annual growth in R&D has been stronger for the academic sector than for any other R&D-performing sector except the nonprofit sector.** During this period, academic R&D rose from 0.23 to 0.35 percent of the gross domestic product.
- **The academic sector performs more than half of the basic research performed in the United States.** Academic R&D activities have been highly concentrated at the basic research end of the R&D spectrum since the late 1950s. In 2002, an estimated 74 percent of academic R&D expenditures went for basic research, 22 percent for applied research, and 4 percent for development.
- **The Federal Government continues to provide the majority of funds for academic R&D, although its share has been declining steadily over the past 3 decades.** The Federal Government provided 59 percent of the funding for R&D performed in academic institutions in 2001, down from 68 percent in 1972.
- **After the Federal Government, academic institutions performing R&D provided the second largest share of academic R&D support.** Except for a brief downturn in the first half of the 1990s, the institutional share of academic R&D support has been increasing steadily during the past 3 decades, nearly doubling to reach 20 percent in 2001.
- **Industrial R&D support to academic institutions has grown more rapidly (albeit from a small base) than support from all other sources during the past 3 decades.** Industry's share was 6.8 percent in 2001, compared with 2.8 percent in 1972. However, industrial support still accounts for one of the smallest shares of academic R&D funding.
- **The concentration of academic R&D funds among the top research universities diminished between the mid-1980s and mid-1990s but has remained relatively steady since then.** The share of those institutions in the group below the top 100 increased from 17 to 20 percent of all academic R&D funds during this period, balanced by a decline in the top 20 institutions' share.
- **Between 1975 and 2001, there was a relative shift in the share of academic R&D funds received by different S&E fields.** Shares increased for engineering, the life sciences, and the computer sciences and declined for the social sciences; the earth, atmospheric, and ocean sciences; the physical sciences; and psychology.
- **The distribution of Federal and non-Federal funding of academic R&D varies by field.** In 2001, the Federal Government supported about three-fourths of academic R&D expenditures in both physics and atmospheric sciences but one-third or less of the R&D in economics, political science, and the agricultural sciences.
- **Three agencies were responsible for about 86 percent of Federal obligations for academic R&D: the National Institutes of Health (66 percent), the National Science Foundation (12 percent), and the Department of Defense (8 percent).** Federal agencies emphasize different science and engineering fields in their funding of academic research, with some, such as NIH, concentrating their funding in one field and others, such as NSF, having more diversified funding patterns.
- **Total space for academic S&E research increased by more than 38 percent between 1988 and 2001, up from about 112 million to 155 million net assignable square feet.** During this period, very little changed in the distribution of research space across S&E fields: 90 percent of the space continued to be distributed among six fields—the biological sciences, the medical sciences, the agricultural sciences, engineering, the physical sciences, and the earth, atmospheric, and ocean sciences.
- **R&D equipment intensity—the share of all annual R&D expenditures spent on research equipment—has declined dramatically during the past 15 years.** After reaching a high of 7 percent in 1986, R&D equipment intensity declined by about one-third, to 4.6 percent in 2001.

Doctoral Scientists and Engineers in Academia

- **Long-term growth of doctoral scientists and engineers employed at U.S. universities and colleges was slower than that in business, government, and other segments of the economy.** As a result, the academic employment share dropped from 53 to 44 percent during the 1975–2001 period.
- **Full-time faculty positions increased more slowly than postdoc and other full- and part-time positions, especially at research universities.** Those entering research universities in 2001 with recently earned doctorates were more likely to receive postdoc (53 percent) than faculty positions (30 percent). Of those with a doctorate earned 4–7 years earlier who were employed at research universities, less than 40 percent were in tenure track positions in 2001, well below the experience of previous decades.

- **An academic researcher pool outside the regular faculty ranks has grown over the years.** As the faculty share of the academic workforce has declined, more research activity is being carried out by postdocs and others in full-time nonfaculty positions. This change toward nonfaculty research effort was pronounced in the 1990s. A long-term upward trend shows the number of those whose primary activity is research increasing relative to total employment.
- **Among recent doctorate holders employed in academia, the percentage of white males has fallen dramatically, from 73 percent in 1975 to 41 percent in 2001.** This decline has been offset by increases in the hiring of women, Asian/Pacific Islanders, and underrepresented minorities.
- **More than 20 percent of scientists and engineers with U.S. doctoral degrees employed at U.S. universities and colleges in 2001 were foreign born.** Computer sciences and engineering had the highest percentages (39 and 35 percent, respectively), followed by mathematics (28 percent) and the physical, life, and social sciences (from 23 to 19 percent). These estimates are conservative, in that they do not include those with doctorates from foreign institutions.
- **The academic doctoral labor force has been aging during the past quarter of a century.** Both the mean and median age have increased almost monotonically between 1975 and 2001. In 2001, a growing, albeit small, fraction of employment was made up of individuals age 65 or older (4.0 percent) and 70 years or older (1.1 percent). These percentages were slightly higher at research universities than at other academic institutions.
- **Graduate students play a key role in U.S. academic S&E research, and research assistantships were the primary means of support for more than one-fourth of them.** The number of research assistants has risen faster than overall graduate enrollment. A shift is evident away from the physical sciences and into the life sciences, reflecting changes in the field distribution of academic research funds.
- **In most fields, the percentage of academic researchers with Federal support for their work was lower in 2001 than a decade earlier.** Full-time faculty received Federal support less frequently than other full-time doctoral employees, who, in turn, were less frequently supported than postdocs, 74 percent of whom received Federal funds in 2001.
- **In the view of academic researchers, at most a modest shift has taken place during the past decade in the nature of academic R&D.** For both those who identified research as their primary work activity and those who identified it as their primary or secondary activity, the percentage who reported basic research was only slightly smaller in 2001 than in 1993.

Outputs of Scientific and Engineering Research: Articles and Patents

- **The number of U.S. scientific publications has remained essentially flat since 1992, while output has grown strongly in Western Europe and several East Asian countries.** The reasons for the flattening of U.S. output are unknown and are under investigation.
- **Scientific collaboration between institutions has increased significantly over the past 2 decades, particularly between countries.** In 2001, nearly 1 in 5 articles had an international coauthor, compared to 1 in 10 articles in 1988.
- **The United States has the largest share of internationally authored papers and collaborates with the largest number of countries.** The U.S. share, however, has declined as other countries have increased and expanded their ties, mainly with Western Europe, Japan, and several East Asian countries.
- **The S&E literature of the United States is the most widely cited by non-U.S. scientists.** The volume and world share of citations of U.S. S&E literature, however, have been falling as citations of S&E literature from Western Europe and East Asia have increased.
- **The rapid increase in citations of S&E research by U.S. patents suggests the growing importance of science in practical applications of technology.** Over the past 2 decades, citations of research by U.S. patents rose more than 10-fold, primarily because of increases in patents related to the life sciences.
- **More than 3,200 U.S. patents were granted to U.S. academic institutions in 2001, an increase of more than 10-fold since the 1970s.** The bulk of academic patents were granted to a relatively small number of institutions and were highly concentrated in life sciences applications.
- **Increases in licensing income and activity suggest growing effort and success of university commercialization of their products and technology.** Income from licensing was more than $850 million in FY 2001—more than double the amount in FY 1996—and new licenses and options rose by more than half during this period.

Introduction

Chapter Overview

The academic sector is a major contributor to the nation's scientific and technological progress, both through the education and training of scientists and engineers (see chapter 2) and the generation of new knowledge and ideas. These activities advance science and support technological innovation, which in turn enhances economic development. A strong national consensus supports the public funding of academic research, and the Federal Government still provides close to 60 percent of the necessary financial resources, although its role is diminishing. More than half of all academic research and development funds go to the life sciences, and this share increased during the past quarter century, prompting discussion about whether the distribution of funds across disciplines is appropriate.

The number of academic institutions receiving Federal support for R&D activities increased during the past 3 decades, expanding the base of the academic R&D enterprise beyond the traditional research institutions. The academic science and engineering infrastructure, both research space and research equipment, grew over the past decade. However, the percentage of total annual R&D expenditures devoted to research equipment declined.

Doctoral S&E faculty in universities and colleges play a critical role in ensuring an adequate, diverse, and well-trained supply of S&E personnel for all sectors of the economy (see chapter 3). Demographic projections point to the potential for strong enrollment growth and the continuation of several trends: more minority participation, more older students, and more nontraditional students. Future trends for foreign graduate students, however, are uncertain in the wake of the events of September 11, 2001.

In this context, and driven by financial and other pressures, universities and colleges will continue to debate questions about their organization, focus, and mission. These discussions are taking place during a time when academia may be approaching a period of increasing retirements caused by an aging labor force. The extent and nature of replacement hiring into tenure-track faculty positions versus other, more temporary, positions are unresolved questions.

Until recently, positive outcomes and impacts of R&D were taken for granted; however, the R&D enterprise has begun to face demands that it devise means and measures to account for results of specific Federal R&D investments, including those for academic R&D, and for the longer term consequences of those results for valued social ends.[1]

This chapter addresses key issues of the academic R&D enterprise, such as the Federal role in supporting academic research; the distribution of funding across S&E disciplines; the breadth and strength of the academic base of the nation's S&E and R&D enterprise; research facilities and instrumentation at universities and colleges; the role of doctoral S&E faculty, including both their teaching and their research responsibilities; and research outputs in the form of refereed articles, academic patents, licenses, and spinoffs. Comparisons with other countries can be found in chapters 2 and 3.

Chapter Organization

The first section of this chapter discusses trends in the financial resources provided for academic R&D, including allocations across both academic institutions and S&E fields. Because the Federal Government has been the primary source of support for academic R&D for more than half a century, the importance of selected agencies in supporting individual fields is explored in detail. This section also presents data on changes in the number of academic institutions that receive Federal R&D support and then examines the status of two key elements of university research activities: facilities and instrumentation.

The next section discusses trends in the employment of academic doctoral scientists and engineers and examines their activities and demographic characteristics. The discussion of employment trends focuses on full-time faculty, postdocs, graduate students, and other positions. Differences between the nation's largest research universities and other academic institutions are considered, as are shifts in the faculty age structure. The involvement of women and minorities is also examined. Attention is given to participation in research by academic doctoral scientists and engineers, the relative balance between teaching and research, and Federal support for research. Selected demographic characteristics of recent doctorate holders entering academic employment are reviewed.

The chapter concludes with an assessment of two types of research outputs: scientific and technical articles measured by data from a set of journals covered by the Science Citation Index (SCI) and the Social Sciences Citation Index (SSCI) and patents issued to U.S. universities. (A third major output of academic R&D, educated and trained personnel, is discussed in the preceding section of this chapter and in chapter 2.) This section looks specifically at the volume of research (article counts), collaboration in the conduct of research (joint authorship), use in subsequent scientific activity (citation patterns), and use beyond science (citations to the literature on patents). It concludes with a discussion of academic patenting and some returns to academic institutions from their patents and licenses.

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[1] These demands can be seen in both the Government Performance and Results Act (GPRA) of 1993 (Public Law 103-62) and the more recent U.S. Office of Management and Budget R&D Investment Criteria (see http://www.ostp.gov/html/ombguidmemo.pdf). For a discussion of research assessment in the context of the GPRA, see http://www.nsf.gov/sbe/srs/ostp/assess/nstcafse.htm.

Financial Resources for Academic R&D

Academic R&D is a significant part of the national R&D enterprise.[2] To carry out world-class research and advance the scientific knowledge base, U.S. academic researchers require financial resources and research facilities and instrumentation that facilitate high-quality work. Several funding indicators bear on the state of academic R&D, including:

- The level and stability of overall funding
- The sources of funding and changes in their relative importance
- The distribution of funding among the different R&D activities (basic research, applied research, and development)
- The distribution of funding among S&E broad and detailed fields
- The distribution of funding among the various performers of academic R&D and the extent of their participation
- The role of the Federal Government as a supporter of academic R&D and the particular roles of the major Federal agencies funding this sector
- The state of the physical infrastructure (research facilities and equipment)

Individually and in combination, these factors influence the evolution of the academic R&D enterprise and therefore are the focus of this section. The main findings are continued growth in both Federal and nonfederal funding of academic R&D, with a steady relative decline in the role of the Federal government; a substantial increase in funding by the National Institutes of Health (NIH) relative to the other main Federal funding agencies; a relative shift in the distribution of funds among fields, with increasing shares for the life sciences, engineering, and the computer sciences; R&D activity occurring in a wider set of institutions, but with the concentration of funds among the top research universities diminishing only slightly; and continuous growth in academic S&E research space, combined with a large fraction of institutions reporting a need for additional space based on current research commitments.

For a discussion of the nature of the data used in this section, see sidebar, “Data Sources for Financial Resources for Academic R&D.”

Academic R&D Within the National R&D Enterprise

The continuing importance of academia to the nation’s overall R&D effort is well accepted.[3] This is especially true for its contribution to the generation of new knowledge through basic research. Since 1998, academia has accounted for more than half of the basic research performed in the United States.

In 2002, U.S. academic institutions spent an estimated $36 billion, or $33 billion in constant 1996 dollars, on R&D.[4] Academia’s role as an R&D performer has increased during the past 3 decades, rising from about 10 percent of all R&D performed in the United States in the early 1970s to an estimated 13 percent in 2002 (figure 5-1). (For a comparison with other industrial countries, see sidebar, “Comparisons of International Academic R&D Spending.”)

Character of Work

Academic R&D activities are concentrated at the research (basic and applied) end of the R&D spectrum and do not include much development activity.[5] An estimated 96 percent of academic R&D expenditures in 2002 went for research (74 percent for basic and 22 percent for applied) and 4 percent for development (figure 5-2). From the perspective of national research, as opposed to national R&D, academic institutions accounted for an estimated 30 percent of the U.S. total in 2002 (figure 5-1). In terms of basic research alone, the academic sector is the country’s largest performer, currently accounting for an estimated 54 percent of the national total. Between the early 1970s and early 1980s, the academic sector’s share of basic research declined steadily, from slightly more to slightly less than half of the national total. In the early 1990s, its share of the national total began to increase once again.

Growth

Over the course of the past 3 decades (1972–2002), the average annual R&D growth rate (in constant 1996 dollars) of the academic sector (4.5 percent) has been higher than that of any other R&D-performing sector except the nonprofit sector (5.0 percent). (See figure 5-3 and appendix table 4-4 for time series data by R&D-performing sector.) As a proportion of gross domestic product (GDP), academic R&D rose from 0.23 to 0.35 percent during this time period, about a 50 percent increase. (See appendix table 4-1 for GDP time series.)

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[2] Federally funded research and development centers (FFRDCs) associated with universities are reviewed separately and examined in greater detail in chapter 4. FFRDCs and other national laboratories (including Federal intramural laboratories) also play an important role in academic research and education, providing research opportunities for both students and faculty at academic institutions.

[3] For more detailed information on national R&D expenditures, see “National R&D Trends” in chapter 4.

[4] For this discussion, an academic institution is generally defined as an institution that has a doctoral program in science or engineering, is a historically black college or university that expends any amount of separately budgeted R&D in S&E, or is some other institution that spends at least $150,000 for separately budgeted R&D in S&E.

[5] Despite this delineation, the term *R&D* (rather than just *research*) is primarily used throughout this discussion because data collected on academic R&D do not always differentiate between research and development. Moreover, it is often difficult to make clear distinctions among basic research, applied research, and development. For the definitions used in National Science Foundation resource surveys and a fuller discussion of these concepts, see chapter 4.

Data Sources for Financial Resources for Academic R&D

The data used to describe financial resources for academic research and development are derived from four National Science Foundation (NSF) surveys:

- Survey of Federal Funds for Research and Development
- Survey of Federal Science and Engineering Support to Universities, Colleges, and Nonprofit Institutions
- Survey of Research and Development Expenditures at Universities and Colleges
- Survey of Scientific and Engineering Research Facilities

These surveys use similar but not always identical definitions, and the nature of the respondents also differs across the surveys. The first two surveys collect data from Federal agencies, whereas the last two collect data from universities and colleges.*

Data presented in the context section, "Academic R&D Within the National R&D Enterprise," are derived from special tabulations that aggregate NSF survey data on the various sectors of the U.S. economy so that the components of the overall R&D effort are placed in a national context. These data are reported on a calendar-year basis, and the data for 2001 and 2002 are preliminary. Since 1998, these data also attempt to eliminate double counting in the academic sector by subtracting those current expenditures for separately budgeted science and engineering R&D that do not remain in the institution reporting them but are passed through to other institutions. Data in subsequent sections differ in that they are reported on a fiscal-year basis and do not net out the funds passed through to other institutions. Data on major funding sources, funding by institution type, distribution of R&D funds across academic institutions, and expenditures by field and funding source are from the Survey of Research and Development Expenditures at Universities and Colleges. For various methodological reasons, parallel data by field from the NSF Survey of Federal Funds for Research and Development do not necessarily match these numbers.

The data in the section "Federal Support of Academic R&D" come primarily from NSF's Survey of Federal Funds for Research and Development. This survey collects data on R&D obligations from 29 Federal agencies. Data for fiscal years 2002 and 2003 are preliminary estimates based on administration budget proposals and do not necessarily represent actual appropriations. Data on Federal obligations by S&E field are available only for FY 2001. These data are not estimated and refer only to research (basic and applied) rather than to research plus development.

The data in the section "Spreading Institutional Base of Federally Funded Academic R&D" are drawn from NSF's Survey of Federal Science and Engineering Support to Universities, Colleges, and Nonprofit Institutions. This survey collects data on Federal R&D obligations to individual U.S. universities and colleges from the approximately 18 Federal agencies that account for virtually all such obligations. For various methodological reasons, data reported in this survey do not necessarily match those reported in the Survey of Research and Development Expenditures at Universities and Colleges.

Data on facilities are taken from the Survey of Scientific and Engineering Research Facilities. This survey is in the midst of a redesign that will broaden its coverage and include computing and networking capacity as well as research space. Data on research equipment are taken from the Survey of Research and Development Expenditures at Universities and Colleges. Although terms are defined specifically in each survey, in general, facilities expenditures are for fixed items such as buildings, are classified as *capital funds,* often cost millions of dollars, and are not included within R&D expenditures as reported here. Research equipment and instruments (the terms are used interchangeably) are generally movable, purchased with current funds, and are included within R&D expenditures reported here. Because the categories are not mutually exclusive, some large instrument systems could be classified as either facilities or equipment. Expenditures for research equipment are limited to current funds and do not include expenditures for instructional equipment. *Current funds,* as opposed to capital funds, are those in the yearly operating budget for ongoing activities. Generally, academic institutions keep separate accounts for current and capital funds.

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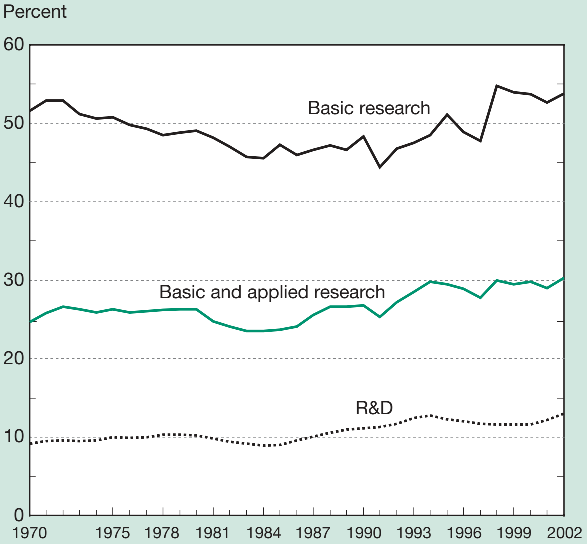
*For descriptions of the methodologies of the NSF surveys, see NSF/SRS 1995a and 1995b and the Division of Science Resources Statistics website, http://www.nsf.gov/sbe/srs/stats.htm.

Figure 5-1
Academic R&D, basic and applied research, and basic research as share of U.S. total of each category: 1970–2002



NOTES: Data for 2001 and 2002 are preliminary. Because of changes in estimation procedures, the character of work data before FY 1998 are not comparable with those of later years. For details on methodological issues of measurement, see *The Methodology Underlying the Measurement of R&D Expenditures: 2002* (NSF/SRS, Arlington, VA, forthcoming). Data are based on annual reports by performers. See appendix tables 4-3, 4-7, 4-11, and 4-15 for data underlying the percentages.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* annual series. See appendix table 5-1.

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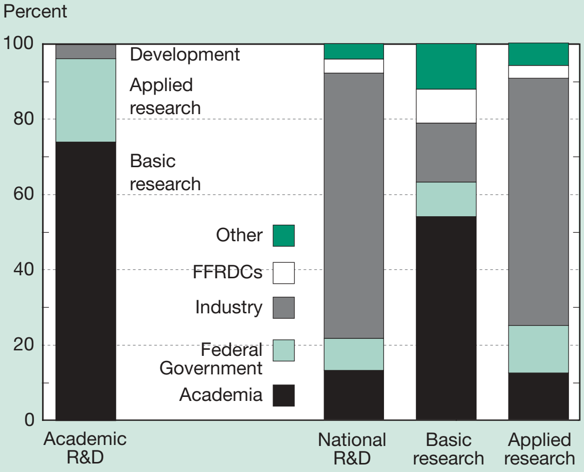
Figure 5-2
Academic R&D expenditures, by character of work, and national R&D expenditures, by performer and character of work: 2002



FFRDC federally funded research and development center

NOTE: Data are preliminary.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* annual series. See appendix tables 4-3, 4-7, 4-11, and 5-1.

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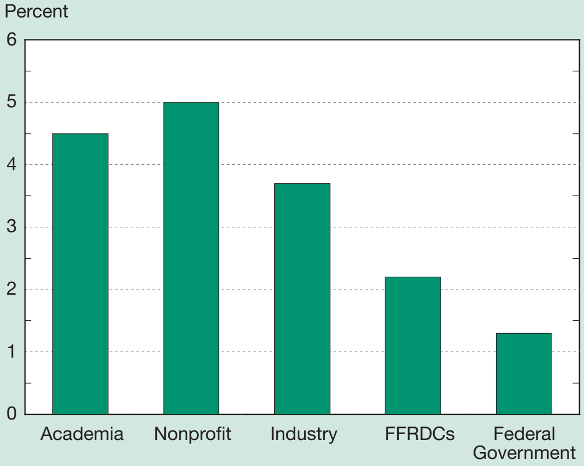
Figure 5-3
Average annual R&D growth, by performer: 1972–2002



FFRDC federally funded research and development center

NOTE: R&D data are on a calendar-year basis. Data for 2001 and 2002 are estimated.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* special tabulations. See appendix table 4-4.

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Major Funding Sources

The academic sector relies on a variety of funding sources for support of its R&D activities. Although the Federal Government continues to provide the majority of funds, its share has declined over the past 3 decades, with most of the decline occurring during the 1980s. In 2001, the Federal Government accounted for 59 percent of the funding for R&D performed in academic institutions, compared with 68 percent in 1972 (appendix table 5-2 and figure 5-4).

Federal support of academic R&D is discussed in detail later in this section; the following list summarizes the contributions of other sectors to academic R&D:[6]

- **Institutional funds.** In 2001, institutional funds from universities and colleges constituted the second largest source of funding for academic R&D, accounting for 20 percent, the highest level during the past half century. Institutional funds encompass three categories: separately budgeted funds from unrestricted sources that an academic institution spends on R&D, unreimbursed indirect costs associated with externally funded R&D projects,

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[6] The academic R&D funding reported here includes only separately budgeted R&D and institutions' estimates of unreimbursed indirect costs associated with externally funded R&D projects, including mandatory and voluntary cost sharing. It does not include departmental research and thus excludes funds, notably for faculty salaries, for research activities that are not separately budgeted.

Comparisons of International Academic R&D Spending

Countries differ in the proportion of their research and development that is performed at institutions of higher education. Among the countries of the Organisation for Economic Co-operation and Development (OECD), R&D performed in the academic sector, as a proportion of total R&D performance, varied from 9 percent in Slovakia to about 60 percent in Turkey, with an overall OECD average of about 17 percent (table 5-1). The U.S. proportion was about 15 percent. (For international comparisons, university-administered federally funded research and development centers are included in U.S. academic R&D.)

A number of factors may account for the differences in the role academia plays in the performance of R&D from country to country. The structure and organization of a country's education system will influence how much R&D is performed in the academic sector. The distribution of a country's R&D expenditures among basic research, applied research, and development is likely to affect the share performed by higher education. Because the academic sector primarily carries out research (generally basic) rather than development activities, countries in which development activities take greater prominence may rely less on the academic sector for overall R&D performance. The importance and strength of other sectors, particularly the industrial sector, in R&D performance also may affect the academic sector's share. (See "International R&D by Performer, Source, and Character of Work" in chapter 4 for more detailed information, including data on the sources of funding for academic R&D in different countries.) Institutional and cultural factors such as the role and extent of independent research institutions, national laboratories, and government-funded or -operated research centers, would also affect the academic sector's share.

Finally, different accounting conventions among countries may account for some of the differences reported. For instance, the national totals for academic R&D for Europe and Canada include the research components of general university funds (GUF) provided as block grants to the academic sector by all levels of government. Therefore, at least conceptually, the totals include academia's separately budgeted research and research undertaken as part of university departmental research activities. In the United States, the Federal Government generally does not provide research support through a GUF equivalent, preferring instead to support specific, separately budgeted R&D projects. On the other hand, some state government funding probably does support departmental research at U.S. public universities. Universities generally do not maintain data on departmental research, which is considered an integral part of instruction programs. U.S. totals thus may be underestimated relative to the academic R&D efforts reported for other countries. Other accounting differences include the inclusion or exclusion of R&D in the social sciences and humanities, the inclusion or exclusion of defense R&D, treatment of capital expenditures, and the level of government included.

Table 5-1
Academic R&D share of total R&D performance, by selected countries: 2000 or 2001
(Percent)

Country	Academic R&D
All OECD	17.2
Australia	27.1
Canada	32.7
Czech Republic	15.7
Finland	17.9
France	18.5
Germany	15.8
Hungary	24.0
Iceland	15.5
Italy	31.0
Japan	14.5
Netherlands	28.8
Poland	32.7
Slovakia	9.0
South Korea	11.3
Spain	29.4
Switzerland	22.9
Turkey	60.4
United Kingdom	20.8
United States	14.9
Non-OECD	
Argentina	35.0
China	8.6
Israel	18.4
Romania	11.3
Russia	5.2
Singapore	23.6
Slovenia	16.6
Taiwan	12.2

OECD Organisation for Economic Co-operation and Development

SOURCE: OECD, *Main Science and Technology Indicators,* 2002. See appendix table 4-45.

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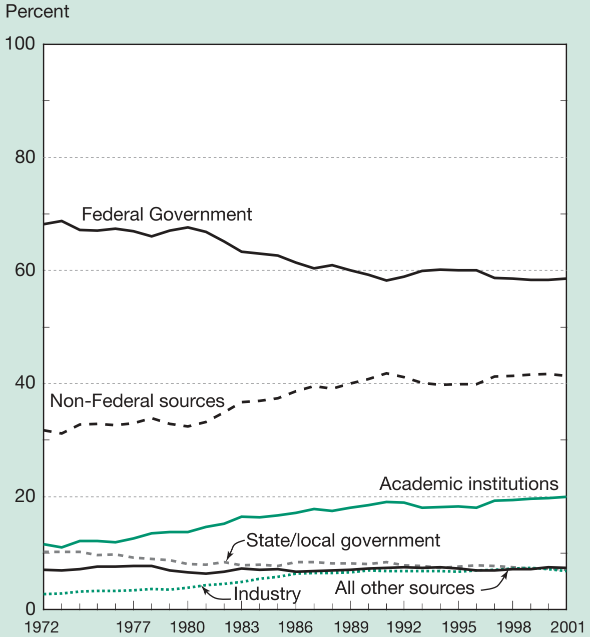
Figure 5-4
Sources of academic R&D funding: 1972–2001



SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), *Academic Research and Development Expenditures: Fiscal Year 2001,* 2003; and NSF/SRS, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 5-2.

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and mandatory and voluntary cost sharing on Federal and other grants. For more detailed discussions of the composition of institutional funds, see sidebar "The Composition of Institutional Academic R&D Funds."

The share of support represented by institutional funds has been increasing during the past 3 decades, except for a brief downturn in the early 1990s. Institutional R&D funds may be derived from (1) general-purpose state or local government appropriations (particularly for public institutions) or Federal appropriations; (2) general-purpose grants from industry, foundations, or other outside sources; (3) tuition and fees; (4) endowment income; and (5) unrestricted gifts. Other potential sources of institutional funds are income from patents or licenses and income from patient care revenues. (See "Patents Awarded to U.S. Universities" later in this chapter for a discussion of patent and licensing income.)

- **State and local government funds.** State and local governments provided 7.1 percent of academic R&D funding in 2001. Since 1980, the state and local share of academic R&D funding has remained between 7 and 9 percent. This share, however, only reflects funds directly targeted to academic R&D activities by state and local governments. It does not include general-purpose state or local government appropriations that academic institutions designate and use to fund separately budgeted research or cover unreimbursed indirect costs.[7] Consequently, the actual contribution of state and local governments to academic R&D is not captured here, particularly for public institutions. See chapter 8, "State Indicators" for some indicators of academic R&D by state.
- **Industry funds.** In 2001, industry provided 6.8 percent of academic R&D funding, a slight decline from its peak of 7.4 percent in 1999. Despite the recent decline, the funds provided for academic R&D by the industrial sector grew faster than funding from any other source during the past 3 decades. However, industrial support still accounts for one of the smaller shares of funding, and support of academia has never been a major component of industry-funded R&D. In 1994, industry's contribution to academic R&D represented 1.5 percent of its total support of R&D, compared with 1.4 percent in 1990, 0.9 percent in 1980, and 0.7 percent in 1972. Between 1994 and 2000, this share declined from 1.5 to 1.2 percent, before beginning to rise slightly again in both 2001 and 2002. (See appendix table 4-4 for time series data on industry-funded R&D and the sidebar "Corporate R&D Strategies in an Uncertain Economy" in chapter 4 for a discussion of how companies intend to spend their R&D budgets.)
- **Other sources of funds.** In 2001, other sources of support accounted for 7.4 percent of academic R&D funding, a level that has stayed almost constant during the past 3 decades. This category of funds includes grants for R&D from nonprofit organizations and voluntary health agencies and gifts from private individuals that are restricted by the donor to the conduct of research, as well as all other sources restricted to research purposes not included in the other categories.

Funding by Institution Type

Although public and private universities rely on the same funding sources for their academic R&D, the relative importance of those sources differs substantially for these two types of institutions (figure 5-5 and appendix table 5-3). In 2001, the most recent year for which data are available, just over 9 percent of R&D funding for all public academic institutions came from state and local funds, about 25 percent from institutional funds, and about 52 percent from the Federal Government. Private academic institutions received a much smaller portion of their funds from state and local governments (about 2 percent) and institutional sources (about 10 percent), and a much larger share from the Federal Government (72 percent). The large difference in the role of institutional funds at public and private institutions is most likely because of a substantial amount of general-purpose state and local government funds that public institutions receive and decide to use for R&D (although data on such

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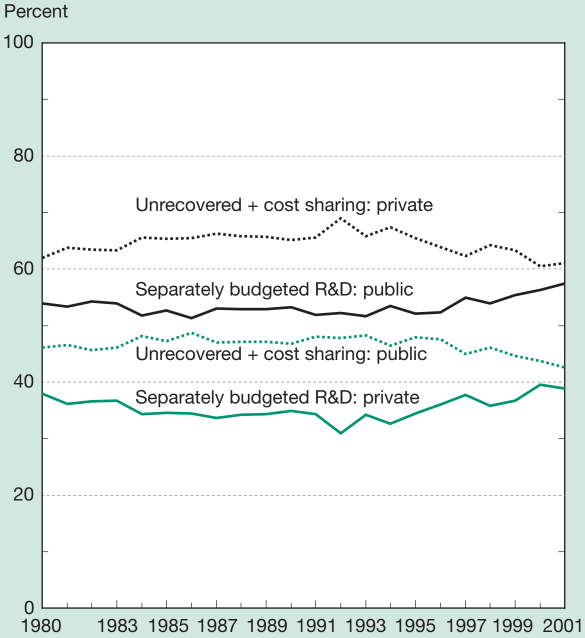
[7] This follows a standard of reporting that assigns funds to the entity that determines how they are to be used rather than to the one that necessarily disburses the funds.

The Composition of Institutional Academic R&D Funds

During the past 3 decades, institutional funds for academic R&D grew faster than funds from any other sources except industry and faster than any other source since 1990 (appendix table 5-2). In 2001, academic institutions committed a substantial amount of their own resources to R&D: roughly $6.5 billion, or 20 percent of total academic R&D. In 2001, the share of institutional support for academic R&D at public institutions (25 percent) was greater than at private institutions (10 percent) (appendix table 5-3). One possible reason for this large difference in relative support is that public universities and colleges' own funds may include considerable state and local funds not specifically designated for R&D but used for that purpose by the institutions. Throughout the 1980s and 1990s, institutional R&D funds were divided roughly equally between two components: separately budgeted institutional R&D funds and mandatory and voluntary cost sharing plus unreimbursed indirect costs associated with R&D projects financed by external organizations. Institutional funds at public and private universities and colleges differ not only in their importance to the institution but also in their composition. Since 1980, from 60 to 70 percent of private institutions' own funds were designated for unreimbursed indirect costs plus cost sharing compared with 43 to 49 percent of public institutions' own funds (figure 5-6).

Figure 5-6
Components of institutional R&D expenditures for public and private academic institutions: 1980–2001



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, special tabulations.

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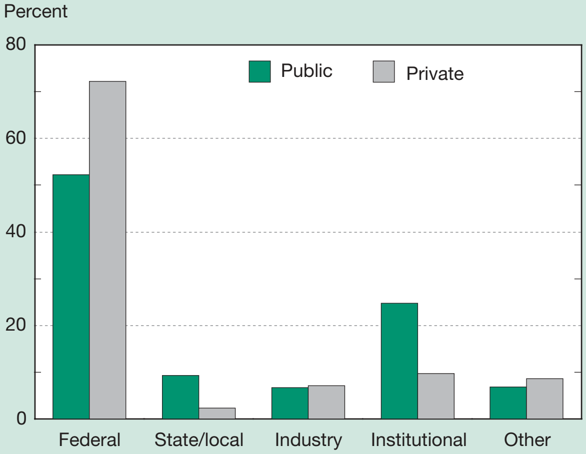
Figure 5-5
Sources of academic R&D funding for public and private institutions: 2001



SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), *Academic Research and Development Expenditures: Fiscal Year 2001,* 2003; and NSF/SRS, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 5-3.

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breakdowns are not collected). Both public and private institutions received approximately 7 percent of their respective R&D support from industry in 2001. Over the past 2 decades, the Federal share of support has declined, and the industry and institutional shares increased for both public and private institutions.

Distribution of R&D Funds Across Academic Institutions

The nature of the distribution of R&D funds across academic institutions has been and continues to be a matter of interest to both those concerned with the academic R&D enterprise and those concerned with local and regional economic development. Most academic R&D is now, and has been historically, concentrated in relatively few of the 3,600 U.S. institutions of higher education.[8] When institutions are

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[8] The Carnegie Foundation for the Advancement of Teaching classified about 3,600 degree-granting institutions as higher education institutions in 1994. See chapter 2 sidebar, "Carnegie Classification of Academic Institutions," for a brief description of the Carnegie categories. These higher education institutions include 4-year colleges and universities, 2-year community and junior colleges, and specialized schools such as medical and law schools. Not included in this classification scheme are more than 7,000 other postsecondary institutions (secretarial schools, auto repair schools, etc.).

ranked by their 2001 R&D expenditures, the top 200 institutions account for about 96 percent of all 2001 R&D expenditures. (See appendix table 5-4 for a more detailed breakdown of the distribution among the top 100 institutions.)

The historic concentration of academic R&D funds diminished between the mid-1980s and mid-1990s but has remained relatively steady since then (figure 5-7). In 1985, the top 10 institutions received about 20 percent of the nation's total academic R&D expenditures and the top 11–20 institutions received 14 percent, compared with 17 and 13 percent, respectively, in 2001. There was almost no change in the share of the group of institutions ranked 21–100 during this period. The composition of the universities in any particular group is not necessarily the same over time, because mobility occurs within groups. For example, only 5 of the top 10 institutions in 1985 were still in the top 10 in 2001. The decline in the top 20 institutions' share was offset by an increase in the share of those institutions in the group not in the top 100. This group's share increased from 17 to 20 percent of total academic R&D funds, signifying a broadening of the base. The discussion in "Spreading Institutional Base of Federally Funded Academic R&D" later in this chapter, under the section "Federal Support of Academic R&D," points to an increasing number of academic institutions receiving Federal support for their R&D activities during the past 3 decades. Many of the newer institutions receiving support are not the traditional research and doctorate-granting institutions.

Figure 5-7
Academic R&D, by rank of universities' and colleges' academic R&D expenditures: 1985–2001

SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), *Academic Research and Development Expenditures: Fiscal Year 2001,* 2003, special tabulations; and NSF/SRS, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 5-4.

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Expenditures by Field and Funding Source

The distribution of academic R&D funds across S&E disciplines often is the result of numerous, sometimes unrelated, funding decisions rather than an overarching plan. Examining and documenting academic R&D investment patterns across disciplines enables interested parties to assess the balance in the academic R&D portfolio. The majority of expenditures for academic R&D in 2001 went to the life sciences, which accounted for 59 percent of all academic R&D expenditures, 58 percent of Federal academic R&D expenditures, and 59 percent of non-Federal academic R&D expenditures (appendix table 5-5). Within the life sciences, the medical sciences accounted for about 31 percent of academic R&D expenditures and the biological sciences for about 18 percent.[9] The next largest block of academic R&D expenditures went to engineering, with about 15 percent in 2001.

The distribution of Federal and non-Federal expenditures for academic R&D in 2001 varied by field (appendix table 5-5). For example, the Federal Government provided about three-fourths of the academic R&D expenditures in both physics and atmospheric sciences but one-third or less of those in economics, political science, and the agricultural sciences.

The decline in the Federal share of academic R&D support is not limited to particular S&E disciplines. The federal share of support for each of the broad S&E fields was lower in 2001 than in 1975 (appendix table 5-6).[10] The most dramatic decline occurred in the social sciences, down from about 55 percent in 1975 to about 38 percent in 2001. The overall decline in Federal share also holds for all the reported S&E detailed fields. However, most of the declines occurred in the 1980s, and many fields did not experience declining Federal shares during the 1990s.

Although the total expenditures for academic R&D in constant 1996 dollars increased in every field between 1975 and 2001 (figure 5-8 and appendix table 5-7), the R&D emphasis of the academic sector, as measured by its S&E field shares, changed during this period (figure 5-9). Relative shares of academic R&D:

- Increased for engineering, the life sciences, and the computer sciences
- Remained roughly constant for mathematics
- Declined for psychology; the earth, atmospheric, and ocean sciences; the physical sciences; and the social sciences

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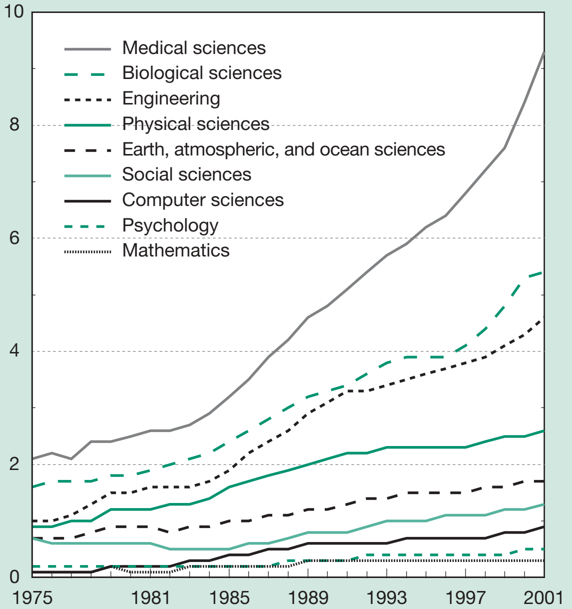
[9] The medical sciences include fields such as pharmacy, veterinary medicine, anesthesiology, and pediatrics. The biological sciences include fields such as microbiology, genetics, biometrics, and ecology. These distinctions may be blurred at times, because boundaries between fields often are not well defined.

[10] In this chapter, the *broad* S&E fields refer to the physical sciences; mathematics; computer sciences; earth, atmospheric, and ocean sciences; life sciences; psychology; social sciences; other sciences (not elsewhere classified); and engineering. The more disaggregated fields of S&E are referred to as *detailed fields*.

Figure 5-8
Academic R&D expenditures, by field: 1975–2001

Billions of constant 1996 U.S. dollars



NOTE: See appendix table 4-1 for gross domestic product implicit price deflators used to convert current dollars to constant 1996 dollars.

SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), *Academic Research and Development Expenditures: Fiscal Year 2001,* 2003; and NSF/SRS, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 5-7.

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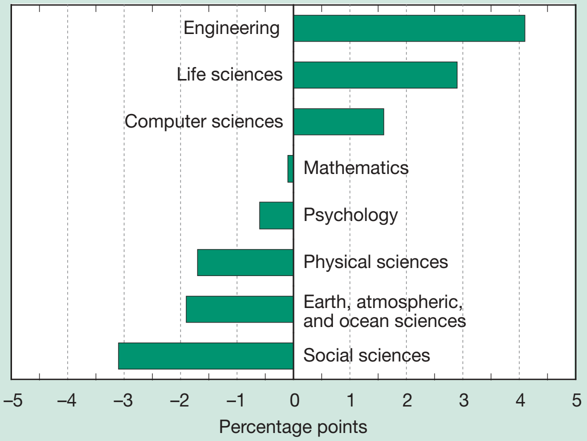
Figure 5-9
Change in share of academic R&D in selected S&E fields: 1975–2001



SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), *Academic Research and Development Expenditures: Fiscal Year 2001,* 2003; and NSF/SRS, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 5-7.

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Although the proportion of all academic R&D funds going to the life sciences increased by only 3 percentage points (from 55.8 to 58.6 percent) between 1975 and 2001, the medical sciences' share increased by more than 7 percentage points (from 23.8 to 31.1 percent) during this period (appendix table 5-7). In the biological sciences, the share of funds was about the same at the beginning and end of the period, whereas in the agricultural sciences, the other major component of the life sciences, the share decreased. Engineering's share of academic R&D increased by about 4 percentage points (from 11.2 to 15.3 percent), whereas the computer sciences' share more than doubled (from 1.3 to 2.9 percent).

The social sciences' proportion of all academic R&D funds declined by more than 3 percentage points (from 7.5 to 4.4 percent) between 1975 and 2001. Within the social sciences, R&D shares for each of the three main fields (economics, political science, and sociology) declined over the period. Psychology's share declined from 2.4 to 1.8 percent. The earth, atmospheric, and ocean sciences' overall share declined by about 2 percentage points (from 7.5 to 5.6 percent), with each of the three detailed fields (atmospheric sciences, earth sciences, and ocean sciences) experiencing an individual decline in share. The physical sciences' overall share also declined during this period (from 10.3 to 8.6 percent). Within the physical sciences, the shares of both physics and chemistry declined, although astronomy's share increased.

Federal Support of Academic R&D

The Federal Government continues to provide the majority of the funding for academic R&D. Its overall contribution is the combined result of a complex set of executive and legislative branch decisions to fund a number of key R&D-supporting agencies with differing missions. Some of the Federal R&D funds obligated to universities and colleges are the result of appropriations that Congress directs Federal agencies to award to projects that involve specific institutions. These funds are known as congressional earmarks. (See sidebar, "Congressional Earmarking to Universities and Colleges.") Examining and documenting the funding patterns of the key funding agencies is key to understanding both their roles and that of the Federal Government overall.

Top Supporting Agencies

Six agencies are responsible for most of the Federal obligations for academic R&D, providing an estimated 96 percent of such obligations in FY 2003 (appendix table 5-8).[11] NIH provided approximately 66 percent of total Federal financing of

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[11] The recent creation of the Department of Homeland Security (DHS) should have major implications for the future distribution of Federal R&D funds, including Federal academic R&D support, among the major R&D funding agencies. DHS's Science & Technology directorate is tasked with researching and organizing the scientific, engineering, and technological resources of the United States and leveraging these existing resources into technological tools to help protect the homeland. Universities, the private sector, and the Federal laboratories are expected to be important partners in this endeavor.

Congressional Earmarking to Universities and Colleges

Academic earmarking, the congressional practice of providing Federal funds to educational institutions for research facilities or projects without merit-based peer review, passed the billion-dollar mark for the first time ever in fiscal year 2000, reached almost $1.7 billion in FY 2001, and exceeded $1.8 billion in FY 2002 (table 5-2). However, not all of these funds go to projects that involve research. The *Chronicle of Higher Education* estimated that 84 percent of earmarked funds in FY 2001 and 87 percent in FY 2002 were for research projects, research equipment, or construction or renovation of research laboratories (Brainard 2002).

Obtaining exact figures for either the amount of funds or the number of projects specifically earmarked for universities and colleges, either overall or for research, is often difficult because of the lack of an accepted definition of academic earmarking and because the funding legislation is often obscure in its description of the earmarked projects. Even with these difficulties, however, a number of efforts were undertaken during the past 2 decades to measure the extent of this activity. Several of these efforts are discussed below.

A report from the Committee on Science, Space, and Technology (U.S. House of Representatives 1993) estimating trends in congressional earmarking indicated that the dollar amount of such earmarks increased from the tens to the hundreds of millions between 1980 and the early 1990s, reaching $708 million in 1992 (table 5-2). In the report, the late Congressman George E. Brown, Jr., (D-CA) stated, “I believe that the rational, fair, and equitable allocation and oversight of funds in support of the nation’s research and development enterprise is threatened by the continued increase in academic earmarks. To put it colloquially, a little may be okay, but too much is too much.”

During the past decade, the *Chronicle of Higher Education* also tried to estimate trends in academic earmarking through an annual survey of Federal spending laws and the congressional reports that explain them. The Chronicle’s latest analysis showed that after reaching a peak of $763 million in 1993, earmarked funds declined more than 60 percent over the next 3 years, reaching a low of $296 million in FY 1996. After 1996, however, earmarks began to increase once again. Congress directed Federal agencies to award at least $1.837 billion for such projects in FY 2002. A record number of institutions received earmarks in FY 2002.

The Office of Management and Budget (OMB) has also recently attempted to provide budget estimates of earmarked funds. In its FY 2001 budget submission to Congress, OMB included a new category of Federal funding for research: research performed at congressional direction (OMB 2002). This consists of intramural and extramural research in which funded activities are awarded to a single performer or collection of performers. Competitive selection is limited or nonexistent, or, where there is competitive selection, the research is outside the agency’s primary mission and being undertaken at Congress’ direction via legislation, report language, or other means. The total reported for this activity is about $2 billion in both FY 2001 and FY 2002. The data are not disaggregated by type of performer.

Finally, the American Association for the Advancement of Science (AAAS) has also recently undertaken an effort to identify congressionally designated, performer-specific R&D projects not appearing in agency budget requests (AAAS 2003). AAAS estimates that R&D earmarks totaled $1.4 billion in FY 2003, down slightly from the FY 2002 estimate of $1.5 billion. Although these estimates include earmarks to all types of R&D performers, the bulk of them are assumed to go to academic institutions.

Given the difficulties in defining and identifying earmarks discussed earlier, it is informative that the recent estimates by the *Chronicle,* OMB, and AAAS are of the same order of magnitude. The estimates indicate that in recent years, about 5 to 6 percent of all academic R&D funds were earmarked.

Table 5-2
Funds for congressionally earmarked academic research projects: 1980–2002
(Millions of dollars)

Year	Earmarked funds
1980	11
1981	0
1982	9
1983	77
1984	39
1985	104
1986	111
1987	163
1988	232
1989	299
1990	248
1991	470
1992	708
1993	763
1994	651
1995	600
1996	296
1997	440
1998	528
1999	797
2000	1,044
2001	1,668
2002	1,837

SOURCES: 1980–92: U.S. House of Representatives, *Academic Earmarks: An Interim Report by the Chairman of the Committee on Science, Space, and Technology* (Washington, DC, 1993); 1993–2000: *Chronicle of Higher Education* 46:A29 (July 28, 2000), 47:A20 (August 10, 2001), and 49:A20 (September 27, 2002).

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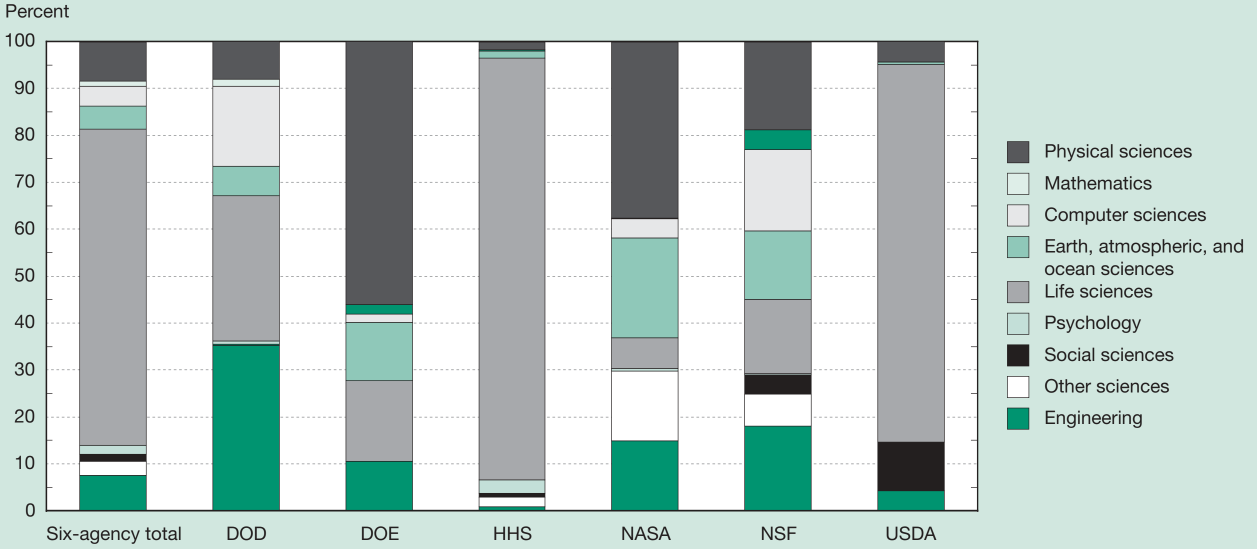
Figure 5-10
Federal agency academic research obligations, by field: FY 2001



DOD Department of Defense; DOE Department of Energy; HHS Department of Health and Human Services; NASA National Aeronautics and Space Administration; NSF National Science Foundation; USDA Department of Agriculture

NOTE: Agencies reported represent approximately 97 percent of Federal academic research obligations.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2001, 2002, and 2003,* forthcoming. See appendix table 5-10.

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academic R&D in 2003. An additional 12 percent was provided by NSF, 8 percent by DOD, 4 percent by the National Aeronautics and Space Administration (NASA); 3 percent by the Department of Energy (DOE); and 2.5 percent by the Department of Agriculture (USDA). The concentration of Federal obligations for academic research is similar to that for R&D (appendix table 5-9). Some differences exist, however, because some agencies place greater emphasis on development (e.g., DOD), whereas others place greater emphasis on research (e.g., NSF).

Between 1990 and 2003, NIH's funding of academic R&D increased the most rapidly, with an estimated average annual growth rate of 7.2 percent per year in constant 1996 dollars, increasing its share of Federal funding from just above 50 percent to an estimated 66 percent. NSF and NASA experienced the next highest rates of growth: 3.8 and 3.4 percent, respectively.

Agency Support by Field

Federal agencies emphasize different S&E fields in their funding of academic research. Several agencies concentrate their funding in one field. The Department of Health and Human Services (HHS) and USDA focus on life sciences, whereas DOE concentrates on the physical sciences. The funding patterns of other agencies, such as NSF, NASA, and DOD, are more diversified (figure 5-10 and appendix table 5-10).

An agency may allocate a large share of its funds to one field yet not be a leading contributor to that field, particularly if it does not spend much on academic research (figure 5-11). In FY 2001, NSF was the lead funding agency in physical sciences (30.6 percent of total funding), mathematics (60 percent), computer sciences (56 percent), and earth, atmospheric, and ocean sciences (40 percent). DOD was the lead funding agency in engineering (43 percent). HHS was the lead funding agency in life sciences (87 percent), psychology (95 percent), and social sciences (39 percent). Within S&E detailed fields, other agencies took the leading role: DOE in physics (50 percent), USDA in agricultural sciences (99 percent), and NASA in astronomy (81 percent) and astronautical engineering (87 percent) (appendix table 5-11).

Spreading Institutional Base of Federally Funded Academic R&D

The number of academic institutions receiving Federal support for their R&D activities has generally increased during the past 3 decades. However, between 1994 and 2000, the number receiving support declined slightly before increasing again in 2000 (figure 5-12).[12] The change in the number supported has occurred almost exclusively among institutions of higher education with Carnegie classifications of comprehensive; liberal arts; 2-year community, junior, and technical; and professional and other specialized schools, rather than among those classified as research or

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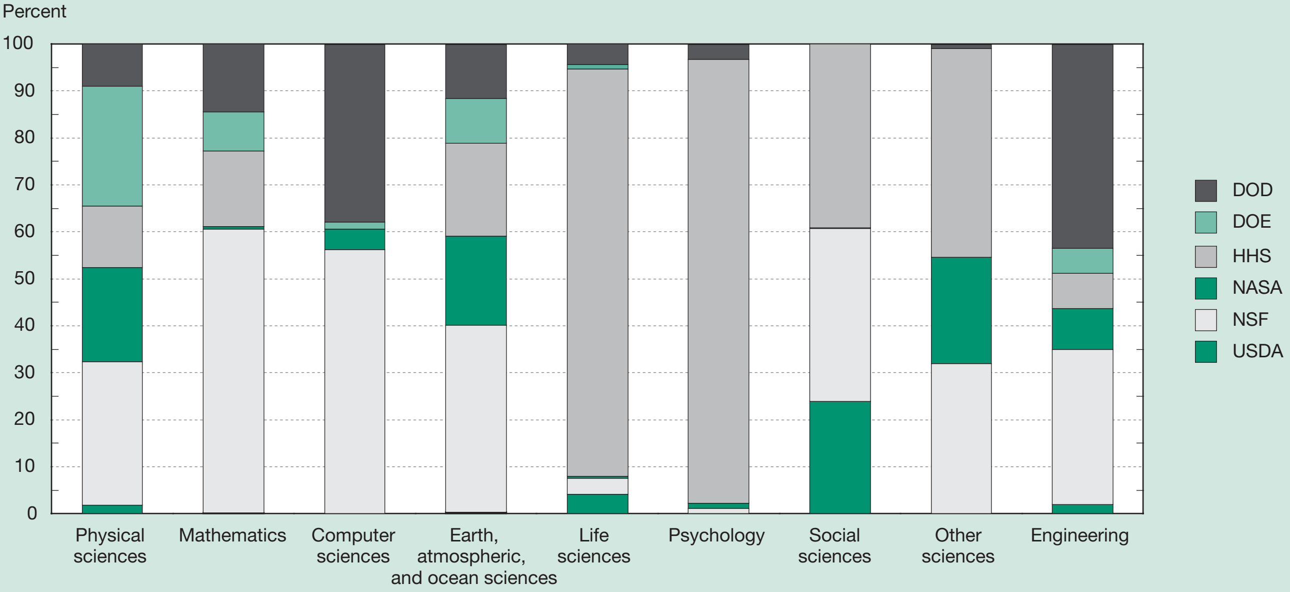
[12] Although the number of institutions receiving Federal R&D support generally increased between 1973 and 1994, a rather large decline occurred in the early 1980s, most likely caused by the decrease in Federal R&D funding for the social sciences during that period.

Figure 5-11
Major agency shares of Federal academic research obligations, by field: FY 2001



DOD Department of Defense; DOE Department of Energy; HHS Department of Health and Human Services; NASA National Aeronautics and Space Administration; NSF National Science Foundation; USDA Department of Agriculture

NOTE: Agencies reported represent approximately 97 percent of Federal academic research obligations.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2001, 2002, and 2003*, forthcoming. See appendix table 5-11.

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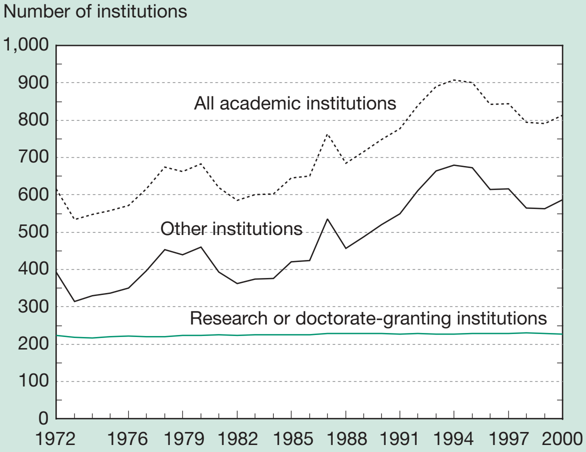
Figure 5-12
Academic institutions receiving Federal R&D support, by selected Carnegie classifications: 1972–2000



NOTES: Other institutions include all institutions except Carnegie research and doctorate-granting institutions. Institutions are designated by the 1994 Carnegie classification code. See Carnegie Foundation for the Advancement of Teaching, *A Classification of Institutions of Higher Education* (Princeton, NJ: Princeton University Press, 1994). For more information on these categories, see chapter 2, "Carnegie Classification of Academic Institutions."

SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), *Federal Science and Engineering Support to Universities, Colleges, and Nonprofit Institutions: Fiscal Year 2001,* forthcoming; and NSF/SRS, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 5-12.

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doctorate-granting institutions. The number of such institutions receiving Federal support more than doubled between 1973 and 1994, rising from 315 to 680, but then dropped to 587 in 2000 (appendix table 5-12). These institutions' share of Federal support also increased between 1973 and 1994, from about 10 percent to above 13 percent. Their share even continued to increase after 1994, reaching just over 15 percent in 2000.

Academic R&D Facilities and Equipment

The condition of the physical infrastructure for academic R&D, especially the state of research facilities and equipment, is a key factor in the continued success of the U.S. academic R&D enterprise.[13]

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[13] An important element of research infrastructure, *cyberinfrastructure,* is not discussed in this report but will be discussed in future editions as more information about this important component becomes available. A recent report has concluded that continuing progress in computing, information, and communication technology has made possible a cyberinfrastructure on which to build new types of S&E knowledge environments and organizations and to pursue research in new ways and with increased efficacy (NSF 2003).

Facilities

Total Space. The amount of academic S&E research space[14] grew continuously between 1988 and 2001. During this period, total academic S&E research space increased by more than 38 percent, from about 112 to 155 million net assignable square feet.[15]

The distribution of academic research space across S&E fields changed only slightly between 1988 and 2001 (appendix table 5-13). About 90 percent of current academic research space continues to be concentrated in six S&E fields:

- Biological sciences (21 percent in 1988 and 2001)
- Medical sciences (17 percent in 1988 and 18 percent in 2001)
- Agricultural sciences (16 percent in 1988 and 17 percent in 2001)
- Engineering (14 percent in 1988 and 17 percent in 2001)
- Physical sciences (14 percent in 1988 and 12 percent in 2001)
- Earth, atmospheric, and ocean sciences (6 percent in 1988 and 5 percent in 2001).

Adequacy. Survey respondents were asked to rate the adequacy of their research space in 2001.[16] Slightly less than 30 percent of S&E research space was rated as adequate (table 5-3). However, the adequacy of this space differed across S&E fields. The fields with the largest proportion of research space reported as adequate were mathematics (69 percent); social sciences (39 percent); earth, atmospheric, and ocean sciences (38 percent); and psychology (37 percent). Those with the smallest proportion were engineering and medical sciences (each with about 23 percent).

Of the institutions reporting research space in 2001, more than 80 percent reported needing additional space in at least one field.[17] More than 60 percent reported needing additional space in the biological sciences (both in universities and colleges and medical schools), the medical sciences (but only in medical schools), and engineering. In all of these fields (as well as some others), more than 38 percent of these institutions reported needing additional space equal to more than 25 percent of their current research space (table 5-4). Only in mathematics did less than half of the institutions report needing any additional space, although, as noted below, those that reported a need for space needed a relatively large quantity of space as compared with their available space.

For all fields combined, the additional space reported as needed was more than one-fourth of available S&E research space in 2001. For most fields, the additional space needed was between 25 and 35 percent of currently available research space (table 5-3). For computer sciences and mathematics, however, it was approximately 109 and 69 percent, respectively. For the agricultural sciences, the additional space reported as needed was about 11 percent of available space.

Equipment

Expenditures. In 2001, slightly less than $1.5 billion in current funds was spent for academic research equipment. About 83 percent of these expenditures were concentrated in three fields: life sciences (45 percent), engineering (22 percent), and physical sciences (16 percent) (figure 5-13 and appendix table 5-14).

Current fund expenditures for academic research equipment grew at an average annual rate of 4.1 percent (in constant 1996 dollars) between 1983 and 2001. Average annual growth, however, was much higher during the 1980s (7.8 percent) than it was after 1990 (1.9 percent). The growth patterns in S&E fields varied during this period. For example, equipment expenditures for engineering (5.5 percent) and biological sciences (5 percent) grew more rapidly during the 1983–2001 period than did those for the social sciences (0.6 percent) and psychology (1.7 percent).

Federal Funding. Federal funds for research equipment are generally received either as part of research grants, thus enabling the research to be performed, or as separate equipment grants, depending on the funding policies of the particular Federal agency involved. The importance of Federal funding for research equipment varies by field. In 2001, the social sciences received slightly less than 40 percent of their research equipment funds from the Federal Government; in contrast, Federal support accounted for more than 60 percent of equipment funding in the physical sciences; computer sciences; earth, atmospheric, and ocean sciences; and psychology (appendix table 5-15).

The share of research equipment expenditures funded by the Federal Government declined from about 62 to 55 percent between 1983 and 2001, although not consistently. This overall pattern masks different trends in individual S&E fields. For example, the share funded by the Federal Government actually rose during this period for both the social and the earth, atmospheric, and ocean sciences.

R&D Equipment Intensity. R&D equipment intensity is the percentage of total annual R&D expenditures from current funds devoted to research equipment. This propor-

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[14] In addition to examining the amount and adequacy of research space, past volumes of *Indicators* also looked at a number of other issues, including new construction, repair and renovation, condition of research space, and unmet needs. However, the 2001 Survey of Scientific and Engineering Research Facilities was limited in scope and did not cover many of the elements covered in previous surveys. A redesigned survey with a broader scope is being planned. In addition to collecting data on research space, the redesigned survey will also include a section on computing and networking capacity. For earlier information, see *Science and Engineering Indicators – 2002* (NSB 2002) and *Scientific and Engineering Research Facilities: 1999* (NSF/SRS 2001).

[15] *Research space* here refers to net assignable square feet (NASF) within facilities (buildings) in which S&E research activities take place. NASF is defined as the sum of all areas (in square feet) on all floors of a building assigned to, or available to be assigned to, an occupant for a specific use, such as instruction or research. Multipurpose space within facilities (e.g., an office) is prorated to reflect the proportion of use devoted to research activities. NASF data on total space are reported at the time of the survey.

[16] The following definitions were used in the survey: *adequate,* sufficient amount of space to support all the needs of current S&E research program commitments in the field; *inadequate,* insufficient space to support the needs of current S&E research program commitments in the field, or nonexistent but needed; and *not applicable,* no space reported.

[17] Survey respondents who indicated that the amount of space in a field was inadequate were requested to report the amount of additional space needed. Therefore, additional space needed in a field was intended to reflect space needed for current S&E research commitments in that field.

Table 5-3
Status of academic S&E research space, by field: 2001

	Available space	Space reported adequate		Space needed	
Field	Millions NASF	Millions NASF	Percent	Millions NASF	Percent[a]
All fields	147.5	42.7	29.0	40.4	27.4
Physical sciences	18.3	5.9	32.5	4.6	24.9
Mathematics	0.9	0.6	68.8	0.6	69.1
Computer sciences	2.1	0.6	26.9	2.2	108.5
Earth, atmospheric, and ocean sciences	7.7	2.9	37.5	2.0	25.7
Agricultural sciences	25.6	7.6	29.8	2.7	10.6
Biological sciences	31.9	8.5	26.6	10.0	31.5
Universities and colleges	19.4	4.5	23.1	5.7	29.3
Medical schools	12.4	4.0	32.0	4.3	34.9
Medical sciences	26.3	6.0	22.8	9.0	34.1
Universities and colleges	7.5	2.4	32.5	2.1	28.3
Medical schools	18.8	3.5	18.9	6.8	36.4
Psychology	3.4	1.3	37.0	1.1	31.3
Social sciences	4.3	1.7	38.5	1.5	34.3
Other sciences	2.8	2.0	71.8	0.5	17.5
Engineering	24.2	5.7	23.3	6.2	25.7

NASF net assignable square feet

[a] Percent of available space.

NOTES: Values for available research space do not match national totals because data were not imputed for the question on adequacy. Available space is calculated only for institutions that responded to the adequacy question. Details may not add to totals because of rounding. Percents are based on unrounded numbers.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Scientific and Engineering Research Facilities: 2001,* NSF 02-307 (Arlington, VA, 2002).

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Table 5-4
Institutions reporting need for additional S&E research space, by field: 2001

(Percent)

		Space needed[a]			
Field	None	Total	Less than 10	10–25	More than 25
All fields	17.7	82.3	13.3	18.3	50.7
Physical sciences	40.6	59.4	7.4	10.8	41.2
Mathematics	60.9	39.1	2.2	4.1	32.8
Computer sciences	43.3	56.7	1.6	3.5	51.6
Earth, atmospheric, and ocean sciences	47.7	52.3	6.5	10.1	35.7
Agricultural sciences	43.0	57.0	19.6	8.4	29.0
Biological sciences					
Total	33.8	66.2	8.8	12.5	44.9
Universities & colleges	37.1	62.9	7.7	11.1	44.1
Medical schools	33.7	66.3	8.2	14.5	43.6
Medical sciences					
Total	39.6	60.4	5.4	14.4	40.6
Universities & colleges	48.0	52.0	5.7	9.3	37.0
Medical schools	27.1	72.9	6.3	25.2	41.4
Psychology	47.2	52.8	5.9	5.1	41.8
Social sciences	47.1	52.9	6.0	9.3	37.6
Other sciences	63.6	36.4	4.2	7.6	24.6
Engineering	37.8	62.2	10.0	13.6	38.6

[a] Percent of current space.

NOTE: Data are based only on institutions reporting research space in a given field.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Scientific and Engineering Research Facilities: 2001,* NSF 02-307 (Arlington, VA, 2002).

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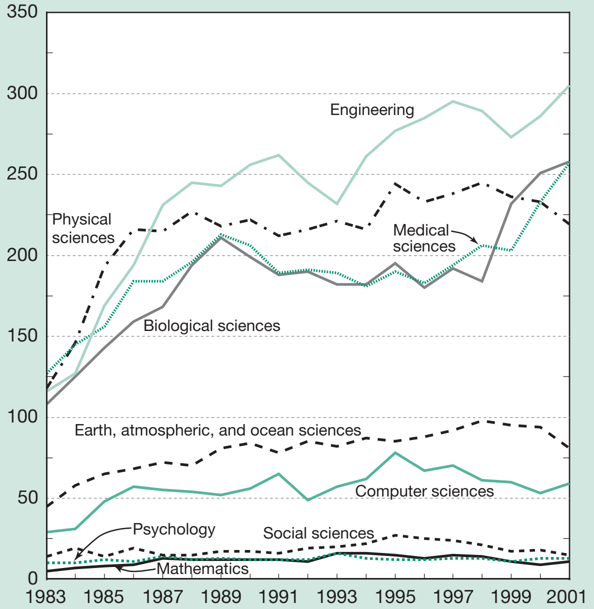
Figure 5-13

Current fund expenditures for research equipment at academic institutions, by field: 1983–2001

Millions of constant 1996 U.S. dollars



NOTE: See appendix table 4-1 for gross domestic product implicit price deflators used to convert current dollars to constant 1996 dollars.

SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), *Academic Research and Development Expenditures: Fiscal Year 2001,* 2003; and NSF/SRS, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 5-14.

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tion was lower in 2001 (4.6 percent) than it was in 1983 (5.7 percent), although it peaked in 1986 (7 percent) (appendix table 5-16). R&D equipment intensity varies across S&E fields. It tends to be higher in the physical sciences (about 9 percent in 2001) and lower in the social sciences (1.2 percent) and psychology (2.4 percent). For the two latter fields, these differences may reflect the use of less equipment, less expensive equipment, or both.

There has been recent congressional interest in this issue. Congress has asked NSF to reinstate the National Survey of Academic Research Instrumentation, last conducted in 1994, to determine the extent to which a lack of equipment and instrumentation prevents the academic research community from undertaking cutting-edge, world-class science.

Doctoral Scientists and Engineers in Academia

U.S. universities and colleges are major contributors to the nation's scientific and technological progress. They generate new knowledge and ideas that are vital to the advancement of science and form the basis of technological innovation. Concurrently, they also develop the highly trained talent needed to use and improve the knowledge base. In addition, academia increasingly plays an active role in the generation and use of new products, technologies, and processes.

The confluence of these key functions: the pursuit of new knowledge, the training of the people in whom it is embodied, and its exploitation toward generating innovation makes academia a national resource whose vitality rests in the scientists and engineers who work and study there. Especially important are those with doctoral degrees who do the research, teach and train the students, and stimulate or help to produce innovation.[18] Who are they, how are they distributed, what do they do, how are they supported, and what do they produce?

Employment and research activity at the 125 largest research-performing universities in the United States merit special attention.[19] These institutions exert a major influence on the nation's academic science, engineering, and R&D enterprise. They enroll 23 percent of full-time undergraduates and award 32 percent of all bachelor's degrees and 38 percent of those in S&E fields. These baccalaureate holders, in turn, are the source of 56 percent of the nation's S&E doctorate holders with a U.S. baccalaureate and more than 60 percent of those who are employed in academia and engaged in R&D as their primary work function. Moreover, these institutions conduct more than 80 percent of academic R&D (as measured by expenditures) and produce the bulk of both academic articles and patents. (See "Outputs of Scientific and Engineering Research: Articles and Patents" later in this chapter.)

Growth in academic employment over the past half century reflected both the need for teachers, driven by increasing enrollments, and an expanding research function, largely supported by Federal funds.[20] Because of the interrelationship between academic teaching and research, much of the discussion deals with the overall academic employment of S&E doctorate holders, specifically, the relative balance between faculty and nonfaculty positions, demographic composition, faculty age structure, hiring of new doctorate holders, trends in work responsibilities, and trends in Federal support. This section also discusses different estimates of the nation's academic R&D workforce and effort and considers whether a shift has been occurring away from basic research toward more applied R&D activities.

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[18] *Innovation* is the generation of new or improved products, processes, and services. For more information, see chapter 6.

[19] This set of institutions comprises the Carnegie Research I and II universities, based on the 1994 classification. These institutions have a full range of baccalaureate programs, have a commitment to graduate education through the doctorate, award at least 50 doctoral degrees annually, and receive Federal support of at least $15.5 million (1989–91 average); see Carnegie Foundation for the Advancement of Teaching (1994). The other Carnegie categories include master's (comprehensive) universities and colleges; baccalaureate (liberal arts) colleges; 2-year community and junior colleges; and specialized schools such as engineering and technology, business and management, and medical and law schools. The classification has since been modified, but the older schema is more appropriate to the discussion presented here.

[20] Trends in S&E indicators relating to research funding are discussed in the first section of this chapter, "Financial Resources for Academic R&D."

The main findings are a relative shift in employment of S&E doctorate holders away from the academic sector toward other sectors; a slower increase in full-time faculty positions than in postdoc and other full- and part-time positions; a relative shift in hiring away from white males toward women and minorities; an aging academic doctoral labor force; a decline in the share of academic researchers who receive Federal support; and growth of an academic researcher pool outside the regular faculty ranks.

Trends in Academic Employment of Doctoral Scientists and Engineers

Academic employment of S&E doctorate holders reached a record high of 245,500 in 2001.[21] However, long-term growth in the number of these positions over the past quarter century was slower than in business, government, and other segments of the economy. Growth in the academic sector was also much slower in the 1990s than it was in the 1970s and 1980s (table 5-5). As a result, the share of all S&E doctorate holders employed in academia dropped from about 53 to 44 percent during the 1975–2001 period (table 5-6). Although the share of those with recently awarded degrees also declined between 1975 and 2001 (from 52 to 49 percent), in 2001 it was still larger than the overall academic employment share for S&E doctorate holders.[22] Within academia, growth in employment of S&E doctorate holders was slower at the major research universities than at other academic institutions. Appendix table 5-17 breaks down academic employment by type of institution.

Table 5-6
S&E doctorate holders employed in academia, by years since doctorate: Selected years, 1975–2001
(Percent)

Years since doctorate	1975	1981	1991	2001
Employed doctorate holders	53.4	49.7	44.7	44.0
3 or fewer	51.9	49.2	47.5	48.8
4–7	52.6	46.9	42.7	41.6
More than 7	54.3	50.6	44.7	43.9

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

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Table 5-5
Average annual growth rates for employment of S&E doctorate holders in U.S. economy: 1975–2001
(Percent)

Sector	1975–2001	1975–81	1981–91	1991–2001
All sectors	3.1	5.0	3.4	1.7
Academia	2.4	3.7	2.3	1.5
Research universities	1.9	3.6	2.1	0.7
All other	2.8	3.8	2.7	2.4
Business	4.2	7.5	2.2	4.2
Government	3.7	5.0	2.3	4.4
Other	3.3	5.1	8.7	–2.9

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

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Hiring at Research Universities and Public Institutions

Employment growth over the past decade was much slower at the research universities than at other academic institutions. From 1991 to 2001, doctoral S&E employment at research universities grew by less than 1 percent annually, whereas employment at other institutions increased by 2.4 percent annually. During the same period, employment increased less rapidly at public universities and colleges than at their private counterparts (0.9 versus 1.4). However, this pattern held only at research universities (0.4 versus 1.4) and not at other academic institutions (1.6 versus 1.4) (figure 5-14, table 5-5, and appendix table 5-18).

All Academic S&E Doctoral Employment

Trends in academic employment of S&E doctorate holders suggest movement away from the full-time faculty position as the academic norm. During the past quarter century, overall academic employment of S&E doctorate holders grew from 134,100 in 1975 to 245,500 in 2001 (appendix table 5-19). However, during this period, full-time faculty positions increased more slowly than postdoc and other full- and part-time positions. This trend accelerated during the past decade (table 5-7). Between 1991 and 2001, the number

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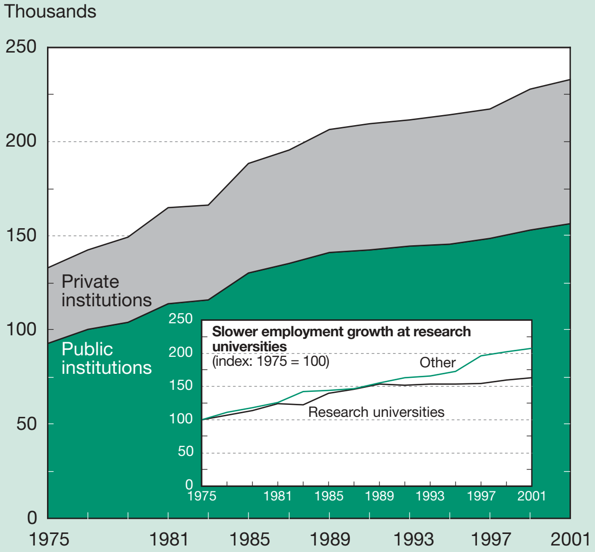
[21] The academic doctoral S&E workforce includes those with a doctorate in an S&E field in the following positions: full and associate professors (referred to as senior faculty); assistant professors and instructors (referred to as junior faculty); postdocs; other full-time positions such as lecturers, adjunct faculty, research and teaching associates, and administrators; and part-time positions of all kinds. Unless specifically noted, data on S&E doctorate holders refer to persons with an S&E doctorate from a U.S. institution, as surveyed biennially by NSF in the Survey of Doctorate Recipients. All numbers are estimates rounded to the nearest 100. The reader is cautioned that small estimates may be unreliable.

[22] Recently awarded degrees are defined here as those earned at a U.S. university within 3 years of the survey year.

Figure 5-14
S&E doctorate holders employed in public and private universities and colleges: 1975–2001



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-18.

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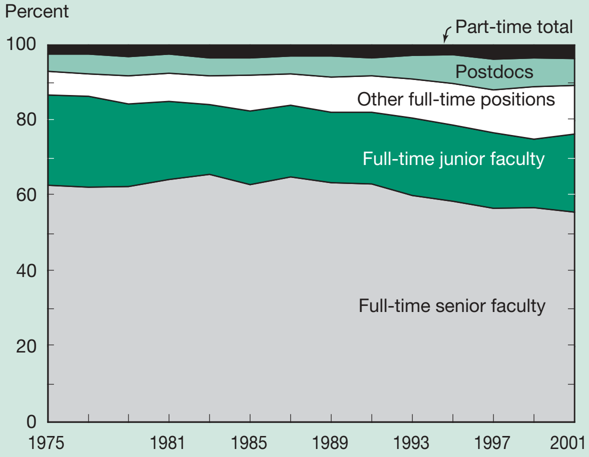
Figure 5-15
S&E doctorate holders, by type of academic appointment: 1975–2001



NOTE: Junior faculty includes assistant professors and instructors; senior faculty includes full and associate professors; other full-time positions include nonfaculty positions such as research associates, adjunct positions, lecturers, and administrative positions.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-18.

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Table 5-7
Average annual growth rates for S&E doctorate holders, by academic position: 1975–2001
(Percent)

Academic position	1975–2001	1975–81	1981–91	1991–2001
All positions	2.4	3.7	2.3	1.5
Full-time faculty	1.8	3.4	2.0	0.8
Professors	2.2	5.1	2.5	0.3
Associate professors	1.4	2.8	1.6	0.3
Junior faculty[a]	1.8	1.3	1.5	2.3
Full-time nonfaculty[b]	5.3	7.2	4.8	4.6
Postdocs	4.1	5.4	1.5	5.8
Part-time	4.0	3.8	6.3	1.9

[a]Assistant professors or instructors.

[b]Positions such as research associates, adjunct positions, lecturers, and administrative positions.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-18.

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of junior faculty rose only modestly (about 20 percent), while the number of senior faculty, full and associate professors, remained static. Meanwhile, full-time nonfaculty positions grew by half, as did postdoc positions.

Figure 5-15 shows the resulting distribution of academic employment of S&E doctorate holders. The share of full-time senior faculty fell from just over 63 percent of total employment in 1991 to less than 56 percent in 2001. The share of junior faculty fluctuated between 18 and 20 percent between 1983 and 1999, before increasing to just below 21 percent in 2001. The overall faculty share was 76 percent of all academic employment in 2001, down from 85 percent in the late 1970s. These employment trends in the past decade occurred as real spending for academic R&D rose by half, retirement of faculty who were hired during the expansionist 1960s increased, academic hiring of young doctorate holders showed a modest rebound, and universities displayed greater interest in the practical application of academic research results, discussed later in this chapter.[23]

Nonfaculty ranks, that is, full- and part-time adjunct faculty, lecturers, research and teaching associates, administrators, and

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[23] It is impossible with the data at hand to establish causal connections among these developments.

postdocs, increased from 37,500 in 1991 to 58,200 in 2001. This 55 percent increase stood in sharp contrast to the 8 percent rise in the number of full-time faculty. Both the full-time nonfaculty and postdoc components grew rapidly between 1991 and 2001, while part-time employment rose more slowly.[24] Part-time employees accounted for only between 2 and 4 percent of all academic S&E doctoral employment throughout the period (appendix table 5-19).

Recent S&E Doctorate Holders

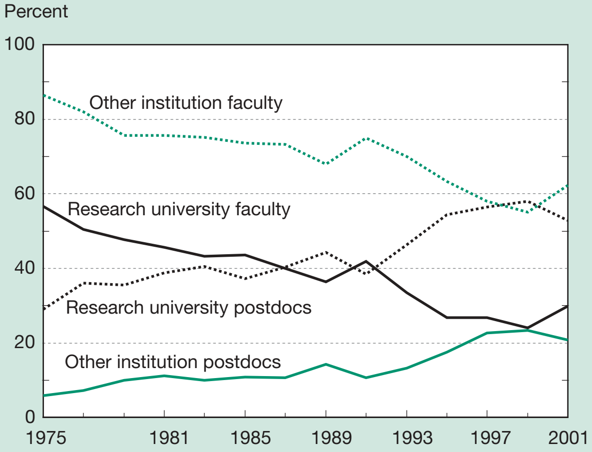
The trends just discussed reflect the entire academic workforce of S&E doctorate holders. Another picture of current trends can be found by looking at the academic employment patterns of those with recently awarded S&E Ph.D.s (degrees earned at U.S. universities within 3 years of the survey year).

Overall, recent doctorate holders who entered academic employment were about as likely to receive postdoc positions as faculty positions. Those in research universities, however, were more likely to be in postdoc than in faculty positions (appendix table 5-20 and figure 5-16). Since 1975, the share of recent doctorate holders hired into full-time faculty positions has been cut by more than one-third overall, from 70 to 44 percent. The decline in such employment at research universities has been relatively steeper, from 57 to 30 percent. Conversely, the overall share of recent S&E doctorate holders who reported being in postdoc positions has risen from 18 to 39 percent (and from 29 to 53 percent at research universities). However, after increasing steadily throughout the 1990s, the share of recent S&E doctorate holders in postdoc positions declined between 1999 and 2001 at both research universities and all other institutions. Whether or not this is the beginning of a trend remains to be seen.

Young Doctorate Holders With Track Records

For those employed in academia 4–7 years after earning their doctorates, the picture looks quite similar: about 63 percent had faculty rank in 2001, compared with about 87 percent in the mid-1970s, with the trend continuing downward since 1991. About half were in tenure-track positions, with only 9 percent already tenured. The shares of both those in tenure-track positions and those with tenure have been declining since 1991, suggesting a continuing shift toward forms of employment outside traditional tenure-track positions (figure 5-17). Trends at research universities are similar. However, at the research universities, the share of those in faculty, tenured, or tenure-track positions is much smaller than at other academic institutions (appendix table 5-20).

Figure 5-16
S&E doctorate holders with recent degrees employed at research universities and other academic institutions, by type of position: 1975–2001



NOTES: Recent doctorate holders are those who earned their degrees within 3 years of the survey year. Faculty are employed full time as full, associate, and assistant professors and instructors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-20.

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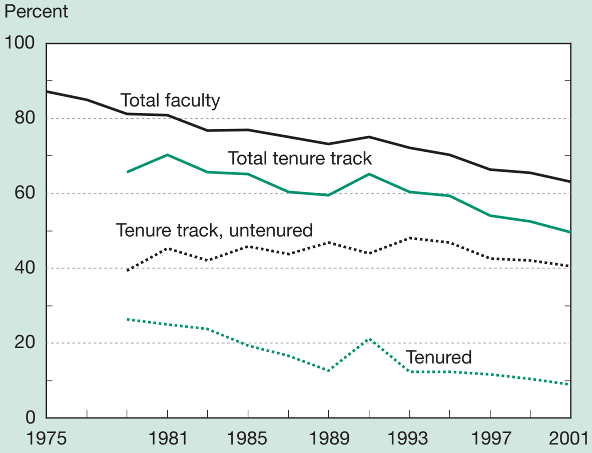
Figure 5-17
Faculty and tenure track status of S&E doctorate holders 4–7 years after receiving degree: 1975–2001



NOTES: Faculty positions include full, associate, and assistant professors and instructors. Tenure track data not available for 1975–77.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-20.

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Shift in Employment

The relative shift toward nonfaculty employment affected almost every major S&E degree field. Although the number of S&E full-time faculty positions increased from 173,100 to 187,400 between 1991 and 2001, two-thirds of this increase occurred in the life sciences, mostly among women. The only other fields in which full-time faculty positions increased by more than 10 percent over this 10-year period were the computer sciences and the earth, atmospheric, and ocean sciences. The share of all doctoral employment held by full-time faculty was lower in 2001 than in 1991 in every broad S&E field.

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[24] For more information on this subject, see “Postdocs” in chapter 3.

However, in many of these fields, the relative shift toward nonfaculty positions appears to have either slowed down or leveled off after 1995 (appendix table 5-19).

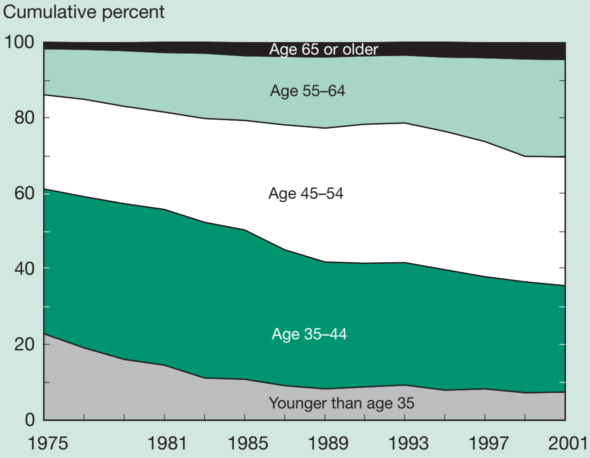
Retirement of S&E Doctoral Workforce

The trend toward fewer faculty and more full-time nonfaculty and postdoc positions is especially noteworthy because academia is approaching a period of increasing retirements. In the 1960s, the number of institutions, students, and faculty in the United States expanded rapidly, bringing many young Ph.D. holders into academic faculty positions. This growth boom slowed sharply in the 1970s, and faculty hiring has since continued at a more modest pace. The result is that increasing numbers of faculty (and others in nonfaculty positions) are today reaching or nearing retirement age.[25]

The Age Discrimination in Employment Act of 1967 became fully applicable to universities and colleges in 1994.[26] It prohibits the forced retirement of faculty at any age, raising concerns about the potential ramifications of an aging professorate for scholarly productivity and the universities' organizational vitality, institutional flexibility, and financial health. These concerns were the focus of a 1991 National Research Council (NRC) study that concluded that "overall, only a small number of the nation's tenured faculty will continue working in their current positions past age 70" (NRC 1991, p. 29), but added, "At some research universities a high proportion of faculty would choose to remain employed past age 70 if allowed to do so" (NRC 1991, p. 38).

Sufficient data have now accumulated to allow examination of some of these concerns. Figure 5-18 shows the age distribution of academic S&E doctorate holders in full-time faculty positions, and figure 5-19 displays the percentage that are 60 years of age or older. The data indicate that individuals age 65 or older (and 70 years or older) constitute a growing share of the S&E doctorate holders employed in academia, suggesting that the Age Discrimination in Employment Act may in fact have had some impact on the age distribution of the professoriate. The data also show that the share of 60- to 64-year-olds was rising well before the act became mandatory, leveled off in the early 1990s, and began to rise again after 1995, reaching just over 10 percent in 2001. A similar progression can be seen for those age 65 or older, who in 2001 made up just over 5 percent of the research universities' full-time faculty and slightly less than 4 percent of other institutions' full-time faculty. The employment share of those older than 70 also rose during most of the past quarter century, reaching about 1.1 percent of all S&E doctorate holders employed in academia in 2001 and 1.2 percent of full-time faculty in 1999 and remaining at that level in 2001 (appendix tables 5-21 and 5-22).

Figure 5-18
Age distribution of academic S&E doctorate holders employed in faculty positions: 1975–2001



NOTE: Faculty are employed full time as full, associate, and assistant professors and instructors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-21.

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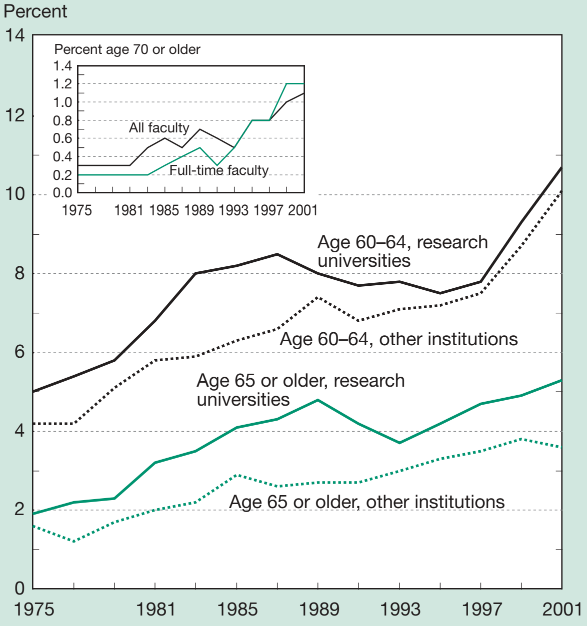
Figure 5-19
Full-time faculty age 60 and older at research universities and other higher education institutions: 1975–2001



NOTE: Faculty positions include full, associate, and assistant professors and instructors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-22.

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[25] See also the discussion of retirements from the S&E workforce in chapter 3, "Science and Engineering Labor Force."

[26] A 1986 amendment to the Age Discrimination in Employment Act of 1967 (Public Law 90-202) prohibited mandatory retirement on the basis of age for almost all workers. Higher education institutions were granted an exemption through 1993 that allowed termination of employees with unlimited tenure who had reached age 70.

Table 5-8
Female and minority S&E doctorate holders employed in academia, by Carnegie institution type: Selected years, 1975–2001
(Percent)

Group and institution type[a]	1975	1981	1991	2001
Female				
Research universities	8.8	12.9	18.8	28.1
Other academic institutions	12.1	15.0	21.2	29.3
Underrepresented minority[b]				
Research universities	1.8	2.6	3.8	5.9
Other academic institutions	3.1	4.5	5.7	7.8
Asian/Pacific Islander				
Research universities	4.9	7.0	8.9	13.3
Other academic institutions	4.1	5.9	6.9	9.3

[a] As defined according to *A Classification of Institutions of Higher Education,* Carnegie Foundation for the Advancement of Teaching (Princeton, NJ, 1994).
[b] Blacks, Hispanics, and American Indian/Alaskan Natives.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

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Increasing Role of Women and Minority Groups

Women and underrepresented minority groups make up a pool of potential scientists and engineers that has not been fully tapped and that, in the case of underrepresented minorities, represents a growing share of U.S. youth, estimated to reach 36 percent of the college-age population by 2020 (appendix table 2-4). Accumulating research points to the importance of role models and mentoring to student success in mathematics, science, and engineering, especially for women and underrepresented minorities.[27] Thus, the presence of women and underrepresented minorities among faculty on college campuses is likely to be a factor in the recruitment of students from both groups to the S&E fields. What were the major hiring trends for them, and what is their current status?

Women

The academic employment of women with S&E doctorates has risen steeply over the past quarter century, reflecting the increase in the proportion of women among recent S&E doctorate holders. The number of women in academia increased more than fivefold between 1975 and 2001, from 13,800 to an estimated 70,500 (appendix table 5-23). This increase is reflected in the rising share of academic positions held by women with S&E doctorates. In 2001, women constituted 29 percent of all academic S&E doctoral employment and just over one-fourth of full-time faculty, up from 10 and 9 percent, respectively, in 1975. Although women made up a smaller share of total employment at research universities than at other academic institutions at the beginning of this period, this differential had almost disappeared by the end of the period (table 5-8). Compared with male faculty, female faculty remain relatively more heavily concentrated in life sciences and psychology, with correspondingly lower shares in engineering, physical sciences, and mathematics.

Women's growing share of academic employment may reflect the confluence of three factors: their rising proportion among new doctorate holders, their somewhat greater predilection for choosing employment in an academic setting than men, and being hired into these positions at somewhat higher rates than men. This historical dynamic is reflected in declining absolute numbers of women and a declining relative share of women as faculty rank increases. In 2001, women constituted 16 percent of full professors, 29 percent of associate professors, and 39 percent of junior faculty, the latter roughly in line with their share of recently earned S&E doctorates.[28] In contrast, both the number and relative share of men increases absolutely from the junior to the senior faculty ranks (See appendix table 5-23 and figure 5-20. For a discussion of some additional factors that may explain these differences, see sidebar "Gender Differences in the Academic Careers of Scientists and Engineers.") This contrasting pattern indicates the recent arrival of significant numbers of female doctorate holders in full-time academic faculty positions. It suggests that the number of women among the faculty will continue to increase, assuming that they stay in academic positions at a rate equal to or greater than that of men.

Underrepresented Minority Groups

The U.S. Census Bureau's demographic projections have long indicated an increasing prominence of minority groups among future college- and working-age populations. With the exception of Asian/Pacific Islanders, these groups tended to be less likely than whites to earn S&E degrees or work

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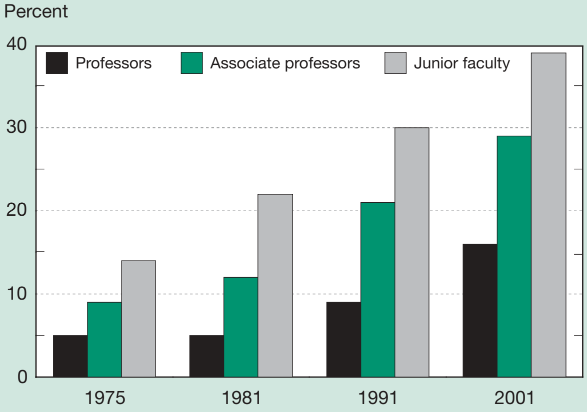
[27] For more information about the effects of mentoring, see *Diversity Works: The Emerging Picture of How Students Benefit,* by Daryl G. Smith and Associates (Washington, DC: Association of American Colleges and Universities, 1997).

[28] See "Doctoral Degrees by Sex" in chapter 2.

Figure 5-20
Female doctoral S&E faculty positions, by rank: Selected years, 1975–2001



NOTE: Junior faculty includes assistant professors and instructors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

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in S&E occupations.[29] Private and governmental groups sought to broaden the participation of blacks, Hispanics, and American Indian/Alaskan Natives in these fields, with many programs targeting their advanced training through the doctorate.

In response, the absolute rate of conferral of S&E doctorates to members of underrepresented minority groups has increased, as has academic employment; but taken together, blacks, Hispanics, and American Indian/Alaskan Natives remain a small percentage of the S&E doctorate holders employed in academia (appendix table 5-24). Because the increases in hiring come from a very small base, these groups still constituted less than 7 percent of both total academic employment and full-time faculty positions in 2001, up from just above 2 percent in 1975. Underrepresented minorities constituted a smaller share of total employment at research universities than at other academic institutions throughout this period (table 5-8). However, among recent Ph.D. holders, they represented almost 9 percent of total academic employment and nearly 10 percent of full-time faculty positions. These trends are similar for all underrepresented minorities and for those who are U.S. citizens (figure 5-21). Compared with whites, blacks tended to be relatively concentrated in the social sciences and psychology and relatively less represented in the physical sciences; the earth, atmospheric, and ocean sciences; mathematics; and the life sciences. The field distribution of Hispanic degree holders is similar to that of white degree holders.

Gender Differences in the Academic Careers of Scientists and Engineers

A recent study supported by the National Science Foundation's Division of Science Resources Statistics (NSF/SRS forthcoming) used data from the NSF biennial Survey of Doctorate Recipients to examine gender differences for four outcomes that reflect successful movement along the academic career path: tenure-track placements, earning tenure, promotion to the rank of associate professor, and promotion to the rank of full professor.

Women scientists and engineers appear to lag behind their male counterparts in moving along the academic career path. A part of these gender differences seems to be related to gender differences in the influence of certain family characteristics. Married women and women with children were less successful than married men with children. That is, married women with children had reduced opportunities, relative to their male counterparts, to be employed in tenure-track positions and to earn tenure. This finding holds for any given time in their careers. Women employed full-time in academia with 14–15 or 20–21 years of postdoctoral experience were more likely than men to be employed in junior ranks and less likely to be full professors.

The study employed multivariate techniques that permitted the statistical control of a large number of factors in addition to gender that might be related to career outcomes. These included measures of human capital, personal and family characteristics, and time of earning the doctorate. A set of models that included female interaction variables as controls was also estimated. These models, which allowed for gender differences in the influence of family characteristics on career outcomes, enabled the testing of hypotheses about whether being married and having children affect the careers of women and men differently. The study was careful to measure family characteristics at common points in individuals' postdoctoral careers because of the suspicion that the timing of decisions about marital status and fertility are important.

The study was conducted in two phases. Phase I looked at gender differences in the likelihood that doctorate holders will successfully achieve outcomes at specific points in time along the academic career path. Phase II, longitudinal in nature, considered gender differences in the amount of time doctorate holders take to achieve career milestones. For the most part, both phases came up with similar results.

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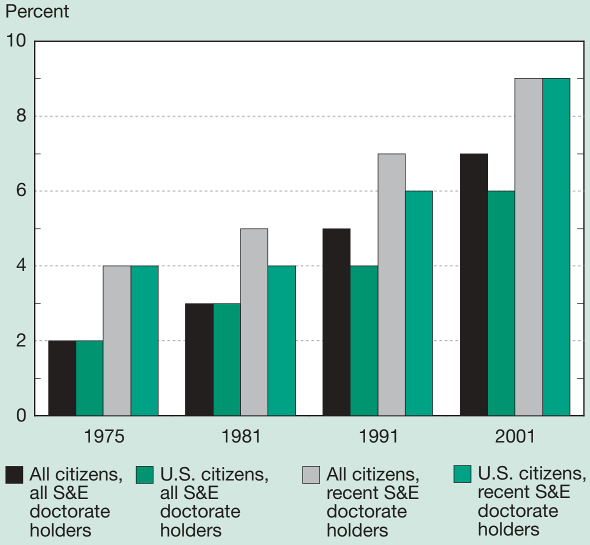
[29] See chapter 2, "S&E Bachelor's Degrees by Race/Ethnicity," "Master's Degrees by Race/Ethnicity," and "Doctoral Degrees by Race/Ethnicity."

Figure 5-21
Underrepresented minority S&E doctorate holders employed in academia, by citizenship status and time since degree: Selected years, 1975–2001



NOTES: The numerator and denominator always refer to the set of individuals defined in the legend, the numerator being underrepresented minorities and the denominator being the entire set. Underrepresented minorities include blacks, Hispanics, and American Indian/Alaskan Natives. Recent doctorate holders are those who earned their degrees within 3 years of the survey.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

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Asian/Pacific Islanders

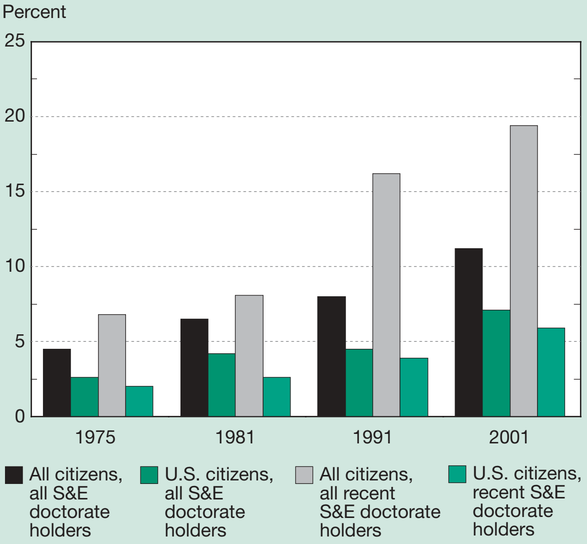
Asian/Pacific Islanders were successful in entering the academic doctoral workforce in S&E, more than doubling in employment share from 5 to 11 percent between 1975 and 2001 (appendix table 5-24). However, a distinction needs to be made between those who are U.S. citizens and those who are not, because the latter group constituted more than 40 percent of this group's doctorate holders in the academic S&E workforce in 2001.[30] The employment share of Asian/Pacific Islanders who are U.S. citizens grew from less than 3 percent of the academic S&E doctoral workforce in 1973 to about 7 percent in 2001. Asian/Pacific Islanders, whether or not they are U.S. citizens, represent a larger percentage of total employment at research universities than at other academic institutions (table 5-8). Limiting the analysis to recent S&E doctorate holders leads to even more dramatic differences between Asian/Pacific Islanders who are U.S. citizens and those who are not. Whereas the share of all recent Asian/Pacific Islander S&E doctorate holders employed in academia rose from just below 7 percent in 1975 to more than 19 percent in 2001, the share of those who are U.S. citizens increased from 2 percent to slightly less than 6 percent (figure 5-22). Although the current employment shares of Asian/Pacific Islanders who are U.S. citizens are almost identical to those of underrepresented minorities, the former group is overrepresented relative to its share of the U.S. population, while the latter is underrepresented.

Compared with whites, Asian/Pacific Islanders as a whole are more heavily represented in engineering and computer sciences and represented at very low levels in psychology and social sciences. This finding holds both for U.S. citizens and for all Asian/Pacific Islanders. In 2001, Asian/Pacific Islanders constituted nearly one-fourth of academic doctoral computer scientists and 18 percent of engineers (appendix table 5-24).

Whites

The role of whites, particularly white males, in the academic S&E doctoral workforce diminished between 1975 and 2001. In 2001, whites constituted 82 percent of the academic doctoral S&E workforce, compared with 91 percent in 1975 (appendix table 5-24). The share of white males declined from about 81 percent to about 59 percent during this period (table 5-9). The decline in the shares of whites and white males who recently received their doctorates was even greater—from 87 to 72 percent and from 73 to 41 percent, respectively (table 5-9). Part of the decline is because of the increasing roles played by women, underrepresented minori-

Figure 5-22
Asian/Pacific Islander S&E doctorate holders employed in academia, by citizenship status and time since degree: Selected years, 1975–2001



NOTES: The numerator and denominator always refer to the set of individuals defined in the legend, the numerator being Asian/Pacific Islanders and the denominator being the entire set. Recent doctorate holders are those who earned their degrees within 3 years of the survey.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

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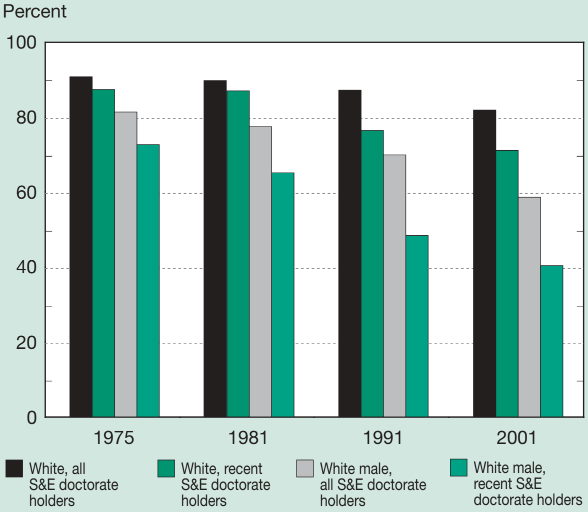
[30] Both the number and share of Asian/Pacific Islander S&E doctorate recipients employed in academia are probably larger than is reported here because those who received S&E Ph.D.s from universities outside the United States are not included in the analysis.

ties, and Asian/Pacific Islanders. However, the decline in the share of white males was exacerbated by a fall in the absolute number of white males in the academic doctoral S&E workforce during the 1990s (figure 5-23).

Foreign-Born S&E Doctorate Holders

An increasing number and share (more than 20 percent) of S&E doctorate holders employed at U.S. universities and colleges are foreign born. Like other sectors of the economy, academia has long relied extensively on foreign talent among its faculty, students, and other professional employees. This reliance increased fairly steadily during the 1980s and 1990s. Figure 5-24 delineates the academic employment estimate of 245,500 U.S.-earned S&E doctorates into those awarded to native-born and foreign-born individuals.[31] However, in addition to foreign-born individuals who hold S&E doctorates from U.S. institutions, U.S. universities and colleges also employ a substantial number of foreign-born holders of S&E doctorates awarded by foreign universities. In *Science & Engineering Indicators – 2002*, a lower value of about 25,000 was estimated for the latter group, which would increase the share of foreign-born Ph.D.-level scientists and engineers employed at U.S. universities and

Figure 5-23
White and white male S&E doctorate holders employed in academia, by time since degree: Selected years, 1975–2001



NOTE: Recent doctorate holders are those who earned their degrees within 3 years of the survey.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

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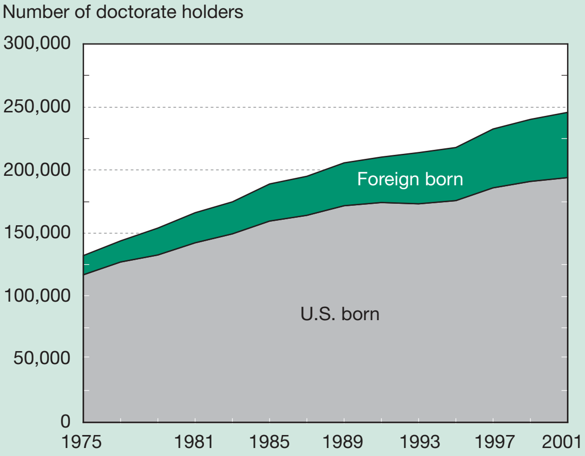
Figure 5-24
Academic employment of U.S. S&E doctorate holders, by place of birth: 1975–2001



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-25.

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Table 5-9
White and white male S&E doctorate holders employed in academia, by years since degree: Selected years, 1975–2001

	1975		1981		1991		2001	
Group	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent
All S&E doctorate holders	134.1	100	167.1	100	210.6	100	245.5	100
White	121.6	91	149.9	90	183.5	87	201.0	82
White male	109.0	81	129.3	77	147.1	70	144.0	59
Recent S&E doctorate holders	23.4	100	20.7	100	25.5	100	28.3	100
White	20.4	87	18.0	87	19.5	77	20.2	72
White male	17.0	73	13.5	65	12.3	48	11.5	41

NOTE: Recent doctorate holders are those who earned their degrees within 3 years of the survey year.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

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[31] In 2001, 57 percent of those who were foreign born were U.S. citizens.

colleges to closer to 30 percent. Because there are no current data on which to base a solid estimate of the number of foreign-born doctorate holders in the United States, and because the available information on the faculty status of holders of doctorates awarded by foreign universities and on which academic institutions employ them is insufficient to draw reliable conclusions, all discussion is based on holders of U.S. doctorates only.

Participation in higher education by foreign-born individuals with U.S.-earned S&E doctoral degrees has increased continuously, both in number and share, since the late 1970s. Academic employment of foreign-born S&E doctorate holders rose from an average of about 12 percent of the total in 1975 to 21 percent in 2001, with some fields reaching considerably higher proportions; for postdocs, the average is almost double that percentage (41 percent) (appendix table 5-25).[32]

Size of Academic Research Workforce

The interconnectedness of research, teaching, and public service in academia makes it difficult to measure the size of the academic research workforce precisely.[33] Therefore, two estimates of the number of academic researchers are presented: a count of those who report that research is their primary work activity, and a count of those who report that research is either their primary or secondary work activity.[34]

Postdocs and those in nonfaculty positions are included in both estimates.[35] To provide a more complete measure of the number of individuals involved in research at academic institutions, a lower-bound estimate of the number of full-time graduate students who support the academic research enterprise is included, based on those whose primary mechanism of support is a research assistantship (RA). This estimate excludes graduate students who rely on fellowships, traineeships, or teaching assistantships for their primary means of support, as well as the nearly 40 percent who are primarily self-supporting. Many, if not most, of these students are also likely to be involved in research activities during the course of their graduate education.[36]

Research as Primary Work Activity

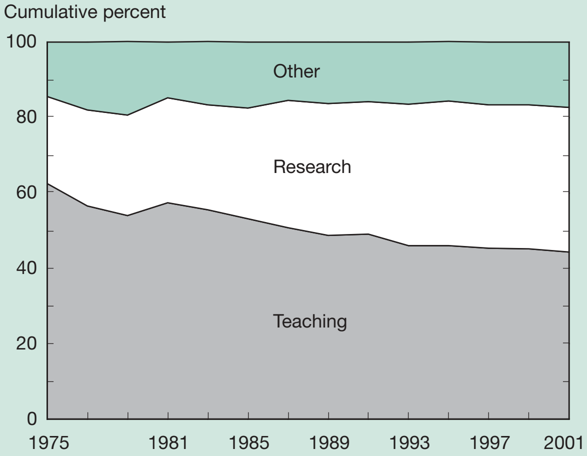
By this measure, the growth of academic researchers with S&E doctorates has been substantial, from 30,800 in 1975 to 93,800 in 2001 (appendix table 5-26). During this period, the number of those with teaching as their primary activity increased much less rapidly, from 83,800 to 109,000. Figure 5-25 displays the resulting shifting proportions in the academic workforce. However, after many years of increase, the proportion of those reporting research as their primary activity leveled off in the 1990s, as did the steep drop in those reporting teaching as their primary activity.

The different disciplines have distinct patterns of relative emphasis on research, but the shapes of the overall trends are roughly the same. The life sciences stand out, with a much higher share identifying research as their primary activity and, correspondingly, a much lower share reporting teaching as their primary activity. Conversely, mathematics and the social sciences have the largest shares identifying teaching as their primary activity and the lowest shares reporting research as their primary activity (figure 5-26).

Research as Either Primary or Secondary Work Activity

The count of academic S&E doctorate holders reporting research as their primary or secondary work activity also shows greater growth in the research than in the teaching component. The number of doctoral researchers in this group increased from 90,600 in 1975 to 172,500 in 2001, whereas teachers increased from 110,400 to 160,600 (appendix table 5-27).[37]

Figure 5-25
Primary work activity of S&E doctorate holders employed in academia: 1975–2001



NOTE: Research includes basic or applied research, development, or design.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-26.

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[32] For a more thorough discussion of the role of foreign scientists and engineers, see chapter 2, "Higher Education in Science and Engineering," and chapter 3, "Science and Engineering Labor Force."

[33] Public service includes activities established primarily to provide noninstructional services beneficial to individuals and groups external to the institution. These activities include community service programs and cooperative extension services.

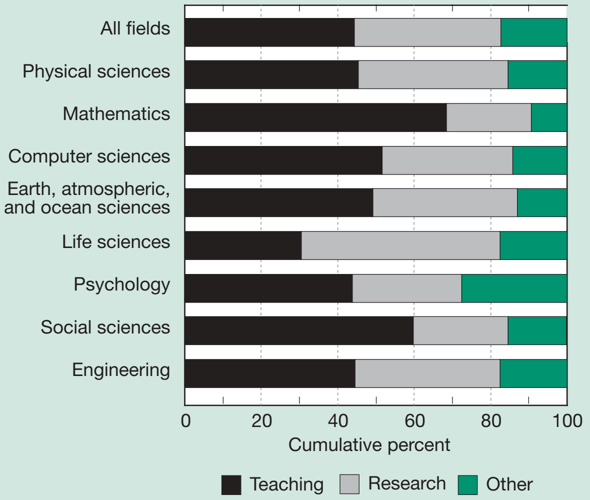
[34] The academic research function encompasses four separate items: basic research, applied research, development, and design. In the following discussion, unless specifically stated otherwise, the term *research* refers to all four.

[35] For technical reasons, the postdoc number excludes holders of S&E doctorates awarded by foreign universities. Data from NSF's Survey of Graduate Students and Postdoctorates in Science and Engineering suggest that in 2001 the number of postdocs with doctorates from foreign institutions was approximately twice that of those with U.S. doctorates. Most of them could be expected to have research as their primary work activity.

[36] For a more detailed treatment of graduate education in general, including the mix of graduate support mechanisms and sources, see chapter 2, "Higher Education in Science and Engineering."

[37] This measure was constructed slightly differently in the 1980s and in the 1990s, starting in 1993, and is not strictly comparable across these periods. Therefore, the crossing over of the two trends in the 1990s could reflect only a methodological difference. However, the very robust trend in the life sciences, where researchers started outnumbering teachers much earlier, suggests that this methodological artifact cannot fully explain the observed trend.

Figure 5-26
Primary work activity of academic S&E doctorate holders employed in academia, by degree field: 2001



NOTE: Research includes basic or applied research, development, or design.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-26.

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The life sciences accounted for much of this trend, with researchers growing from 29,000 to 63,100 and teachers from about the same base of 29,600 to 44,400. The other fields generally included fewer researchers than teachers in the 1970s and early 1980s, but this trend has been reversed for the physical sciences; the earth, atmospheric, and ocean sciences; and engineering.

Graduate Research Assistants

The close coupling of advanced training with hands-on research experience is a key strength of U.S. graduate education. To the count of S&E doctoral researchers for whom research is a primary or secondary work activity can be added an estimate of the number of S&E graduate students who are active in research. The more than 350,000 full-time S&E graduate students (as of 2001) can be expected to contribute significantly to the conduct of academic research.

Graduate RAs were the primary means of support for slightly more than one-fourth of these students. Table 5-10, which shows the distribution of all full-time S&E graduate students and graduate research assistants by field over the past quarter century, indicates that the number of research assistants has grown considerably faster than graduate enrollment, both overall and in most fields. In both graduate enrollment and the distribution of RAs, there was a shift away from the physical sciences and social sciences and into the life sciences, computer sciences, and engineering. In engineering,

Table 5-10
Full-time S&E graduate students and graduate research assistants at U.S. universities and colleges, by degree field: Selected years, 1975–2001

	1975		1981		1991		2001	
Group and degree field	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent
Graduate students	219.6	100	257.3	100	329.3	100	355.1	100
Physical sciences	21.9	10	26.7	10	28.9	9	27.1	8
Mathematics	10.7	5	11.8	5	13.4	4	12.5	4
Computer sciences	4.5	2	13.9	5	16.5	5	30.1	8
Earth, atmospheric, and ocean sciences	9.6	4	11.3	4	11.3	3	10.5	3
Life sciences	63.1	29	69.5	27	100.0	30	108.2	30
Psychology	24.1	11	25.3	10	35.2	11	34.5	10
Social sciences	48.0	22	42.8	17	56.2	17	54.6	15
Engineering	37.8	17	55.9	22	67.8	21	77.6	22
Graduate research assistants[a]	40.0	100	61.0	100	89.9	100	99.7	100
Physical sciences	6.4	16	10.3	17	11.8	13	11.8	12
Mathematics	0.6	2	1.0	2	1.5	2	1.4	1
Computer sciences	0.7	2	2.1	3	3.9	4	4.2	4
Earth, atmospheric, and ocean sciences	2.8	7	3.7	6	4.7	5	6.5	6
Life sciences	11.3	28	17.9	29	29.3	33	31.0	31
Psychology	2.2	6	3.1	5	4.6	5	4.9	5
Social sciences	4.8	12	5.1	8	7.2	8	7.8	8
Engineering	11.0	28	17.9	29	27.0	30	32.2	32

[a] Graduate students with primary research assistantship support.

NOTE: Details may not add to totals and percents may not sum to 100 because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering.

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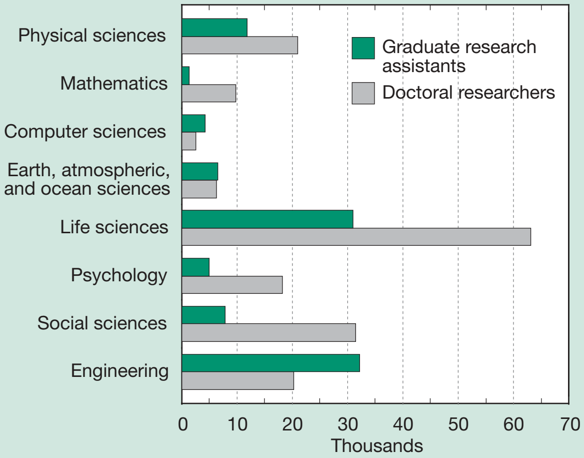
the physical sciences, and the earth, atmospheric, and ocean sciences the proportion of RAs is relatively high in relation to graduate enrollment. In the life sciences, the proportion of RAs relative to enrollment is more balanced, possibly reflecting the heavier reliance of these fields on postdoctoral researchers.

Adding graduate research assistants (full-time graduate students whose primary mechanism of support is an RA) to the count of S&E doctoral researchers for whom research is either the primary or secondary activity yields a more complete lower-bound measure of the number of individuals involved in academic research. With the caveats introduced earlier, the number of academic researchers in 2001 estimated in this way is approximately 272,000 (figure 5-27 and appendix table 5-28). It is worth noting that in both computer sciences and engineering, the number of graduate research assistants exceeded the number of doctoral researchers.

Deployment of Academic Research Workforce

This section discusses the distribution of the academic research workforce across types of institutions, positions, and fields. It also examines differences in research intensity by looking at S&E doctorate holders involved in research activities relative to all S&E doctorate holders employed in academia.

Figure 5-27
Estimated number of graduate research assistants and doctoral researchers in academia, by degree field: 2001



NOTES: Doctoral researchers include those whose primary or secondary work activity is basic or applied research, development, or design. Graduate research assistants are full-time graduate students with primary research assistantship support.

SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), Survey of Doctorate Recipients, special tabulations; and NSF/SRS, Survey of Graduate Students and Postdoctorates in Science and Engineering. See appendix table 5-28.

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Distribution Across Types of Academic Institutions

The majority of the research workforce is concentrated in the research universities (appendix table 5-29). In 2001, the research universities employed 49 percent of S&E doctorate holders in academic positions, 57 percent of S&E doctorate holders reporting research as their primary or secondary activity, 71 percent of S&E doctorate holders whose primary activity was research, and 80 percent of S&E graduate research assistants.

Over the years, however, the research universities' share of S&E doctorate holders reporting research as their primary or secondary activity has declined, possibly reflecting these universities' decreasing shares of total and Federal expenditures for academic research. The research universities' losses were offset by gains in several other types of institutions.[38] Table 5-11 provides a long-term overview of the changes in these institutional distributions.

Distribution Across Academic Positions

A pool of academic researchers outside the regular faculty ranks has grown over the years, as shown by the distribution of S&E doctorate holders reporting research as their primary or secondary activity across different types of academic positions: faculty, postdoctoral fellows, and all other types of appointments (table 5-12 and appendix table 5-30). The faculty share declined from about 87 percent in 1975 to about 77 percent in 2001 (approximately the same as the change in overall employment share). The decline in faculty share was balanced by increases in the shares for both postdocs and those in other nonfaculty positions. However, the distribution across different types of academic positions for those reporting research as their primary activity changed little during this period.

Distribution Across S&E Fields

The distributions of total academic S&E doctoral employment and S&E doctoral academic research personnel (using various measures) across broad fields are not identical. Comparison of these distributions provides one possible measure of relative research intensity across fields. Researcher proportions in excess of a field's employment share could be deemed to indicate greater research intensity. Table 5-13 suggests that by these measures, research intensity is greater in the life sciences than in the other fields and relatively less in mathematics, psychology, and the social sciences (appendix table 5-31).

Research Intensity of Academic Institutions

A measure of research intensity similar to the one used above can be used to examine the change in research intensity in academia over time. In this case, the change in the relative importance given to R&D in U.S. universities

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[38] For a more detailed discussion of these shifts, see *Changes in Federal Support for Academic S&E and R&D Activities Since the 1970s* (NSF/SRS forthcoming).

Table 5-11

S&E doctorate holders and graduate research assistants employed in academia, by Carnegie institution type: 1975–2001

(Percent distribution)

Group and institution type	1975–81	1981–91	1991–2001
All employed S&E doctorate-holders	100.0	100.0	100.0
Research universities	54.2	53.6	50.6
Doctorate-granting institutions	11.5	11.3	11.2
Comprehensive institutions	18.1	18.5	18.4
All others	16.3	16.6	19.8
Researchers[a]	100.0	100.0	100.0
Research universities	65.4	63.0	58.3
Doctorate-granting institutions	10.8	11.0	11.5
Comprehensive institutions	12.3	13.6	14.7
All others	11.5	12.5	15.6
Graduate research assistants[b]	100.0	100.0	100.0
Research universities	87.5	84.6	80.9
Doctorate-granting institutions	9.2	9.9	11.4
Comprehensive institutions	2.1	3.3	4.8
All others	1.2	2.2	2.8

[a] Research is primary or secondary work activity.

[b] Graduate students with primary research assistantship support.

NOTES: Institutional designation is according to *A Classification of Institutions of Higher Education,* Carnegie Foundation for the Advancement of Teaching (Princeton, NJ, 1994). Freestanding schools of engineering and technology are included under comprehensive institutions. “All others” includes freestanding medical schools, 4-year colleges, specialized institutions, and institutions without a Carnegie code. Percents may not sum to 100 because of rounding.

SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), Survey of Doctorate Recipients, special tabulations; and NSF/SRS, Survey of Graduate Students and Postdoctorates in Science and Engineering. See appendix table 5-29.

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Table 5-12

S&E doctorate holders employed in academia, by involvement in research and position: Selected years, 1975–2001

Involvement in research and position	1975	1985	1995	2001
	Thousands			
All academic employment	134.1	190.2	217.5	245.5
Research as primary or secondary activity	90.6	115.2	153.5	172.5
Research as primary activity	30.8	55.9	83.0	93.8
	Percent distribution			
All academic employment	100.0	100.0	100.0	100.0
Full-time faculty	86.8	82.5	78.8	76.3
Postdocs	4.6	4.6	7.7	7.1
Other full- and part-time positions	8.6	12.9	13.5	16.6
Research as primary or secondary activity	100.0	100.0	100.0	100.0
Full-time faculty	87.1	82.6	79.3	77.3
Postdocs	6.5	6.8	10.5	9.6
Other full- and part-time positions	6.4	10.6	10.2	13.1
Research as primary activity	100.0	100.0	100.0	100.0
Full-time faculty	69.5	70.7	68.2	67.0
Postdocs	18.5	13.4	18.2	16.6
Other full- and part-time positions	12.3	15.9	13.7	16.4

NOTES: Full-time faculty includes full, associate, and assistant professors plus instructors. Other full- and part-time positions include full-time nonfaculty such as research associates, adjunct positions, lecturers, administrative positions, and part-time positions of all kinds. Percents may not sum to 100 because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-30.

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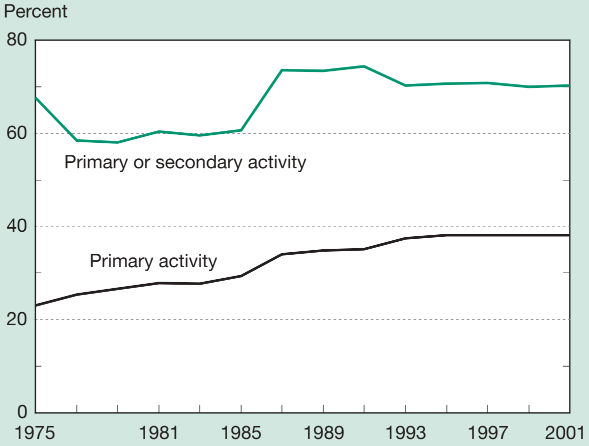
and colleges is addressed in terms of the number of S&E doctoral research personnel relative to all S&E doctoral employment in academia. Two measures of S&E doctoral personnel are used: the number reporting research as their primary or secondary work activity and the number reporting research as their primary work activity. These measures tell somewhat different stories, and the reader is cautioned that they are suggestive rather than definitive.

The number of S&E doctorate holders reporting research as primary or secondary activity relative to all S&E doctoral employment declined between 1975 and 1977; was relatively constant at about 60 percent from the mid-1970s to the mid-1980s, when R&D funds grew relatively slowly; then rose again in 1987 to about 74 percent; dropped to about 70 percent in 1993; and has remained relatively constant at that level since then (figure 5-28). On the other hand, the share of S&E doctorate holders in academia who reported research as their primary activity experienced a long-term upward trend from the mid-1970s through the mid-1990s, increasing from about 23 percent of total employment to about 38 percent, where it has remained since 1995. The latter trend is similar for each of the broad S&E fields except for the computer sciences, which is a new field relative to the others (table 5-14). These trends may indicate an overall strengthening of the research function in academia, at least through the mid-1990s.

Figure 5-28
S&E doctorate holders employed in academia, by involvement in research: 1975–2001



NOTE: Percent refers to S&E doctorate holders involved in research as percentage of all S&E doctorate holders.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-30.

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Government Support of Academic Doctoral Researchers

Academic researchers rely on the Federal Government for a significant share, about 60 percent, of their overall research support. The institutional and field distributions of these funds are well documented, but little is known about their distribution across researchers. This section presents data from reports by S&E doctorate holders in academia about the presence or absence of Federal support for their work. However, nothing is known about the magnitude of these funds to individual researchers. (See sidebar, “Interpreting Federal Support Data.”)

Appendix table 5-32 shows the percentage of academic S&E doctorate holders who received Federal support for their work, broken out by field. The analysis examines the overall pool of doctoral S&E researchers as well as young doctorate holders, for whom support may be especially critical in establishing a productive research career.

Table 5-13
S&E doctorate holders employed in academia, by degree field and involvement in research: 2001
(Percent distribution)

Degree field	All academic employment	Involvement in research: Primary or secondary activity	Involvement in research: Primary activity
All fields	100.0	100.0	100.0
Physical sciences	12.4	12.2	12.7
Mathematics	6.1	5.7	3.5
Computer sciences	1.5	1.5	1.4
Earth, atmospheric, and ocean sciences	3.3	3.6	3.3
Life sciences	34.3	36.6	46.6
Psychology	12.4	10.5	9.3
Social sciences	19.1	18.2	12.4
Engineering	10.8	11.7	10.7

NOTE: Percents may not sum to 100 because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-31.

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Table 5-14
S&E doctorate holders employed in academia who reported research as primary activity, by degree field: Selected years, 1975–2001
(Percent)

Degree field	1975	1985	1995	2001
All fields	23.0	29.4	38.2	38.2
Physical sciences	27.1	34.8	42.9	39.1
Mathematics	13.6	19.9	22.6	22.1
Computer sciences	na	50.0	32.3	34.5
Earth, atmospheric, and ocean sciences	20.5	30.8	40.6	37.7
Life sciences	36.8	46.2	52.7	51.9
Psychology	14.9	19.9	28.4	28.6
Social sciences	11.4	13.6	23.1	24.9
Engineering	17.2	22.1	36.6	37.9

na not applicable

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-31.

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Academic Scientists and Engineers Who Receive Federal Support

In 2001, the Federal Government provided support to an estimated 45 percent of all S&E doctorate holders in academia, about 74 percent of those for whom research was the primary activity, and about 36 percent of those for whom research was a secondary activity (appendix table 5-32). With the exceptions of engineering and the earth, atmospheric, and ocean sciences, no major shifts appear to have occurred in the overall percentage of those so supported during the 1993–97 period. However, as table 5-15 shows, the 2001 percentages for S&E as a whole and for each of the fields were below those for 1991.

The percentage of S&E doctorate holders in academia who received Federal support differed greatly across the S&E fields. In 2001, this percentage ranged from about 64 percent in the earth, atmospheric, and ocean sciences to about 22 percent in the social sciences (table 5-15 and appendix table 5-32).

Full-time faculty received Federal funding less frequently than other full-time doctoral employees, who, in turn, were supported less frequently than postdocs. In 2001, about 43 percent of full-time faculty, 49 percent of other full-time employees, and 74 percent of postdocs received Federal support. These proportions were lower than those during the latter part of the 1980s, but dropped less for full-time faculty than for postdocs or other full-time positions (appendix table 5-32). It is unclear whether these estimates indicate relatively less generous support or greater availability of funds from other sources, some of which may not flow through university accounts.

Federal Support of Young S&E Doctorate Holders in Academia

Early receipt of Federal support is viewed as critical to launching a promising academic research career. The Federal Government supports young S&E doctorate holders in academia at slightly higher rates than it does the overall academic doctoral S&E workforce. However, the pattern of support for young researchers is similar to that of the overall academic S&E doctoral workforce: those in full-time faculty

Interpreting Federal Support Data

Interpretation of the data on Federal support of academic researchers is complicated by a technical difficulty. Between 1993 and 1997, respondents to the Survey of Doctorate Recipients were asked whether work performed during the week of April 15 was supported by the Federal Government; in most other survey years, the reference was to the entire preceding year; in 1985, it was to 1 month. However, as these data series clearly illustrate, the volume of academic research activity is not uniform over the entire academic year. A 1-week (or 1-month) reference period seriously understates the number of researchers supported over an entire year. Thus, the numbers for 1985 and 1993–97 cannot be compared directly with results for the earlier years or those from the 1999 and 2001 surveys, which again used an entire reference year.

The discussion here compares data for 1999 and 2001 with the earlier series and examines trend information for the mid-1990s using the 1993–97 data points. All calculations express the proportion of those with Federal support relative to the number responding to this question. The reader is cautioned that, given the nature of these data, the trends discussed are broadly suggestive rather than definitive. The reader also is reminded that the trends in the proportion of all academic researchers supported by Federal funds occurred against a background of rising overall numbers of academic researchers.

Table 5-15
S&E doctorate holders employed in academia who received Federal support, by degree field: 1981, 1991, and 2001
(Percent)

Degree field	1981	1991	2001
All fields	42.8	50.3	45.4
Physical sciences	50.4	56.6	53.2
Mathematics	21.3	34.5	31.9
Computer sciences	29.7	49.4	47.2
Earth, atmospheric, and ocean sciences	50.2	66.2	64.1
Life sciences	59.6	65.5	56.6
Psychology	32.7	34.7	34.3
Social sciences	21.8	28.4	21.5
Engineering	51.0	63.2	56.8

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-32.

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positions are less likely to receive Federal support than those in postdoc or other full-time positions (appendix tables 5-32 and 5-33). Overall, about 48 percent of those with recently earned doctorates (within 3 years of the survey) received Federal support. However, about 29 percent of those in full-time faculty positions received support, compared with about 73 percent of those in postdoc positions. The share of postdocs receiving Federal support was relatively low (about 42–57 percent) in some fields (e.g., the social sciences, mathematics, and engineering) and high (80 percent or more) in others (e.g., the physical sciences, computer sciences, and earth, atmospheric, and ocean sciences).

In 2001, young academics who had gained some experience (i.e., those who had received their doctorate 4 to 7 years earlier) received Federal support in proportions similar to those of the academic S&E doctoral workforce as a whole in most fields (appendix tables 5-32 and 5-33 and table 5-16).

Federal Support From Multiple Agencies

About 20 percent of academic S&E doctorate holders who report Federal support indicated they received support from more than one agency in the mid-1970s and early 1980s. This proportion peaked at 30 percent in 1991, and by 2001 declined to 26 percent (table 5-17). Although, as previously indicated, holders of recently awarded doctorates were more likely to receive Federal support than the overall academic S&E doctoral workforce, they were less likely to receive it from more than one agency.

Has Academic R&D Shifted Toward More Applied Work?

Emphasis on exploiting the intellectual property that results from the conduct of academic research is growing. (See next section, "Outputs of Scientific and Engineering Research: Articles and Patents.") Among the criticisms raised about this development is that it can distort the nature of academic research by focusing it away from basic

Table 5-16
S&E doctorate holders employed in academia 4–7 years after receiving degree who received Federal support, by degree field: 1981, 1991, and 2001
(Percent)

Degree field	1981	1991	2001
All fields	46.5	57.4	46.1
Physical sciences	57.9	67.2	54.1
Mathematics	29.7	28.3	42.2
Computer sciences	52.4	66.2	49.2
Earth, atmospheric, and ocean sciences	57.2	76.6	54.1
Life sciences	64.0	70.6	56.4
Psychology	34.7	38.8	34.9
Social sciences	24.3	36.6	21.2
Engineering	65.6	73.2	58.3

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-33.

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Table 5-17
S&E doctorate holders employed in academia receiving Federal support who received it from multiple agencies: Selected years, 1975–2001
(Percent)

S&E doctorate holders	1975	1981	1991	2001
All	20	19	30	26
Recent[a]	15	13	20	17

[a] Doctorate received at U.S. university within 3 years of survey.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

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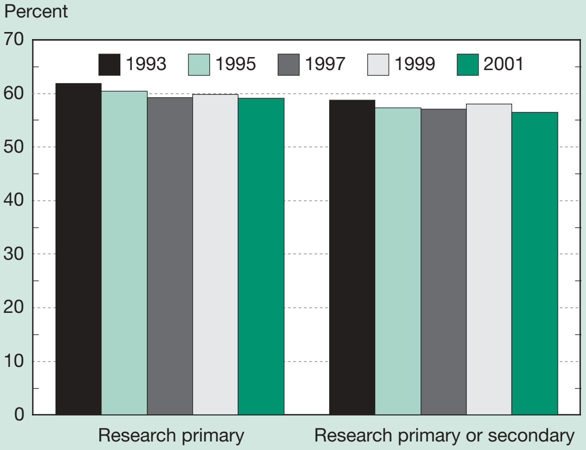
research and toward the pursuit of more utilitarian, problem-oriented questions.

Did such a shift toward applied research, design, and development occur during the 1990s, a period when academic patenting and licensing activities grew considerably? By its very nature, this question is a difficult one to analyze, for a number of reasons. As indicated earlier in the chapter, it is often difficult to make clear distinctions among basic research, applied research, and development. Sometimes basic and applied research can be complements and embodied in the same research. Some academic researchers may obtain ideas for basic research from their applied research activities.

Two indicators can be examined to determine whether any large-scale changes occurred. One indicator is the share of all academic R&D expenditures directed to basic research. Appendix table 5-1 shows that the basic research share increased slightly between 1990 and 1996 and that there was hardly any change in this measure between 1998 and 2002. The second indicator is the response to a question S&E doctorate holders in academia were asked about their primary or secondary work activities, including four R&D functions: basic research, applied research, design, and development.

As figure 5-29 shows, for those employed in academia who reported research as their primary activity, involvement in basic research declined slightly between 1993 and 2001, from 61.9 percent to 59.1—a shift that barely reaches statistical significance. A similar shift occurred for all academic doctoral researchers (from 58.7 percent in 1993 to 56.5 in 2001). The available data, although limited, provide little evidence to date that pressures on academic institutions and faculty to change research agendas led to a shift toward more applied work.

Figure 5-29
S&E doctorate holders in academia involved in research whose primary research activity is basic research: Selected years, 1993–2001



NOTE: S&E doctorate holders involved in research include those whose primary or secondary work activity is basic or applied research, development, or design.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

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Outputs of Scientific and Engineering Research: Articles and Patents

The products of academic research include trained personnel and advances in knowledge. Trained personnel are discussed earlier in this chapter and also in chapter 2. This section presents data on two additional indicators of scientific research output: scientific articles and patents received by U.S. academic institutions. In addition, it presents data on citations to previous scientific work contained in articles and patents.

Articles, patents, and citations provide indicators, albeit imprecise ones, of scientific output, the content and priorities of scientific research, the institutional and intellectual linkages within the research community, and the ties between scientific research and practical application. Data on articles, patents, and citations, used judiciously, enable meaningful comparisons of institutional sectors, scientific disciplines, and nations.

Articles are one key output for scientific research because publication has been the norm for disseminating and validating research results and is crucial for career advancement in most scientific fields. Data on the authorship of articles also provide information on the extent of research collaboration and on patterns and trends in collaboration across institutional, disciplinary, and national boundaries.

Citations provide another measure of scientific productivity by indicating how influential previous research has been. Patterns in citations can show links within and across institutional boundaries. Citations to scientific articles in U.S. patents provide indications of the degree to which technological innovations rely on scientific research.

The number of patents issued to U.S. universities is another indicator of the output of academic science. In addition, it is an indicator of the relationship between academic research and commercial application of new technologies.

Output of U.S.-authored scientific articles has flattened since the early 1990s, while article output grew strongly in Western Europe, Japan, and several East Asian countries during this period. The reasons for the change in the U.S. trend are unknown and are under investigation. Collaboration between institutional authors within and across national boundaries has grown considerably over the past 2 decades. Although the U.S. continues to have the largest share of internationally authored articles, this share has declined over the past 2 decades as countries have expanded and deepened their collaboration with other countries. Patenting and related activities by U.S. academic institutions continued to increase during the 1990s, suggesting the growing effort and success of universities to commercialize their research results and technology.

For a discussion of the nature of the data used in this section, see sidebar, "Data and Terminology."

Worldwide Trends in Article Output

The volume of articles published in the world's key S&E journals is an indicator of the output of scientific and technical research in the United States and other countries. The United States had the largest single share of articles in the world in 2001, accounting for approximately one-third of all articles. When the shares of Japan, Germany, the United Kingdom, and France are added to the United States, these five countries account for nearly 60 percent of all articles published in 2001. Adding other countries of the Organisation for Economic Co-operation and Development (OECD) and other high-income countries increases this share to more than 80 percent of world output (table 5-18). These countries generally also rank high on a per capita output basis. Their wealthy, technically advanced economies enable them to maintain pools of scientists and engineers and the scientific and technical infrastructures their work requires

Table 5-18
OECD share of world S&E article output: 2001
(Percent)

Country	Share
All OECD	82.0
United States	30.9
Japan	8.8
United Kingdom	7.3
Germany	6.7
France	4.8
Other OECD	23.4

OECD Organisation for Economic Co-operation and Development

NOTES: Country shares are based on articles credited to the institutional address of the country. For internationally authored articles, countries are credited the fractional contribution to the article.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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Data and Terminology

The article counts, coauthorship data, and citations discussed in this section are based on science and engineering articles, notes, and reviews published in a slowly expanding set of the world's most influential scientific and technical journals tracked by the Institute for Scientific Information (ISI) Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). These data are not strictly comparable to those presented in previous editions of *Science & Engineering Indicators,* which were based on a fixed ISI journal set. The advantage of the "expanding" set of journals is that it better reflects the current mix of influential journals and articles. The number of journals covered by ISI that published relevant material (i.e., articles, notes, or reviews) was 4,460 in 1988, 4,601 in 1993, 5,084 in 1998, and 5,262 in 2001.

Field designations for articles in the ISI-tracked journals are determined by the classification of the journal in which an article appears. Journal classification, in turn, is based on the patterns of a journal's citations (appendix table 5-34).

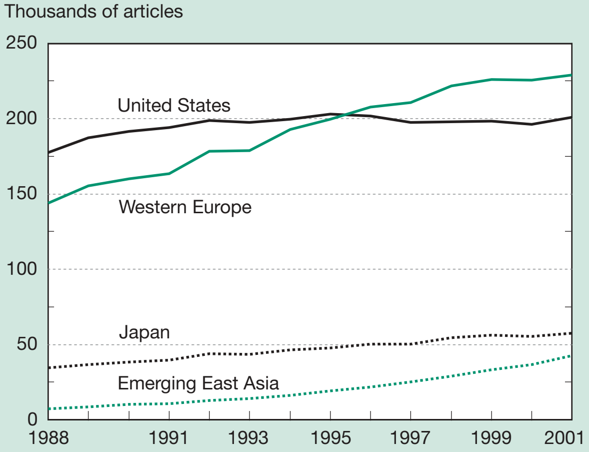
SCI and SSCI give reasonably good coverage of a core set of internationally recognized scientific journals, albeit with some English-language bias. ISI coverage extends to electronic journals, including print journals with electronic versions and electronic-only journals. Journals of regional or local importance may not be covered, which may be salient for the categories of engineering and technology, psychology, the social sciences, the health sciences, and the professional fields, as well as for nations with a small or applied science base.

Author as used here means *institutional author.* Articles are attributed to countries and sectors by the author's institutional affiliation at the time of publication. If an institutional affiliation is not listed on the paper, it would not be attributed to an institutional author. Likewise, *coauthorship* refers to institutional coauthorship: a paper is considered coauthored only if its authors have different institutional affiliations or are from separate departments of the same institution. Multiple authors from the same department of an institution are considered as one institutional author. The same logic applies to cross-sectoral or international collaboration.

All data presented here derive from the Science Indicators database prepared for the National Science Foundation by CHI Research, Inc. The database excludes all letters to the editor, news pieces, editorials, and other content whose central purpose is not the presentation or discussion of scientific data, theory, methods, apparatus, or experiments.

Figure 5-30

Output of S&E articles by selected countries/ regions: 1988–2001



NOTE: Emerging East Asia consists of China, Singapore, South Korea, and Taiwan.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc., and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-35.

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and to provide relatively high levels of financial support for their S&E enterprises.[39]

World article output increased by almost 40 percent from 1988 to 2001, largely driven by growth in Western Europe, Japan, and several emerging East Asian S&T centers (South Korea, Singapore, Taiwan, and China). In contrast, growth in article output by U.S. authors was markedly slower and remained essentially flat after 1992 (figure 5-30). Flattening of output in almost all fields drove the U.S. trend (table 5-19).

The basic picture of broad article trends shows that the nations with the greatest wealth and the most mature S&T infrastructures lost some ground, in relative terms, to developing nations with moderate income levels.[40] Low-income nations experienced little change in their shares of the world's S&E publications (figure 5-31).

Western Europe's article output grew by about two-thirds from 1988 to 2001 and surpassed that of the United States in 1997. Output gains were substantial across most countries, especially many of the smaller and/or newer members of the European Union (EU) (figure 5-30 and appendix table 5-35). This growth may reflect, at least in part, EU and regional programs to strengthen the S&T base, as well as these nations' individual efforts.[41]

Japan's article output increased steadily over the period. It rose at approximately the same pace as Western Europe's, resulting in a two-thirds growth in output. This growth coincided with a substantial increase in Japan's R&D expenditures.

East Asian authors in China, South Korea, Singapore, and Taiwan produced S&E articles at a sharply accelerating pace, attesting to the rapid scientific and technological progress of these economies. Over the 14-year period covered here, article output rose almost 5-fold in China, 6-fold in Singapore and Taiwan, and 14-fold in South Korea. This pushed their collective share of the world total from 1.5 percent in 1988 to 6.6 percent in 2001. On a per capita output basis, China remains well below the world average, whereas the other three rank well above it (table 5-20).

Table 5-19

U.S. article output, by S&E field: Selected years, 1988–2001

Field	1988	1991	1993	1995	1997	1999	2001
All fields	177,662	194,015	197,397	202,887	197,531	198,524	200,870
Clinical medicine	55,016	59,488	61,312	63,367	62,676	63,190	63,709
Biomedical research	27,455	31,177	33,117	35,048	33,661	33,423	34,041
Biology	12,862	13,898	12,671	12,664	12,027	11,271	12,499
Chemistry	13,186	14,681	15,089	14,915	14,375	14,491	14,342
Physics	18,023	20,515	19,602	19,709	18,048	18,074	17,385
Earth/space sciences	8,053	9,113	9,830	10,886	10,540	11,209	11,272
Engineering/technology	11,817	12,838	13,303	13,801	12,907	13,564	13,889
Mathematics	3,880	3,382	3,453	3,190	3,051	3,561	3,657
Social/behavioral sciences	27,370	28,922	29,019	29,307	30,246	29,742	30,075

NOTE: Social/behavioral sciences include social sciences, psychology, health sciences, and professional fields.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-36.

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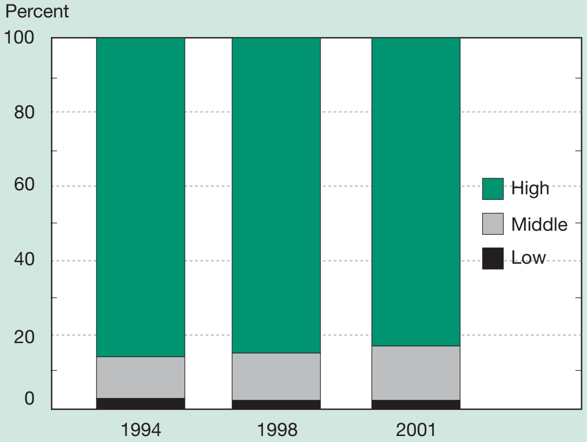
[39] Also see chapter 2, "Higher Education in Science and Engineering"; chapter 4, "U.S. and International Research and Development: Funds and Technology Linkages"; and chapter 6, "Industry, Technology, and the Global Marketplace."

[40] As determined by the World Bank, which classifies countries as high, middle, or low on the basis of their per capita income.

[41] These include the EU 5-year Framework and programs of other pan-European organizations, such as EUREKA, which encourages partnerships between industry, universities, and research institutes with the goal of commercializing research. See European Commission (2001) for a fuller treatment.

Figure 5-31
World S&E articles, by income level of countries: 1994, 1998, and 2001



NOTES: Income classification determined by World Bank, based on per capita income level. Countries without World Bank income classification are excluded.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; National Science Foundation, Division of Science Resources Statistics, special tabulations, and World Bank, *World Development Indicators 2002* (Washington, DC, 2002).

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The output volume of Central and South America grew by more than 8 percent per year. Three countries—Argentina, Brazil, and Chile—generated more than 85 percent of the region's articles in 2001, and all had moderately high per capita incomes, relatively large pools of scientists and engineers, and undertook recent reforms of their economies and scientific enterprises (NSF/SRS, 2000). Article output in Western Asia is influenced by Indian publications, which started to rise in the late 1990s after years of stagnation. India's science community, however, has renewed its debate about the health of its science enterprise in light of much higher S&E article growth in the emerging East Asian countries.[42] Scientists in North Africa and the Middle East increased their article output by about 3 percent annually, but increases in Israeli output, accounting for the bulk of the region's publications, lagged behind the overall pace of growth. The output of countries in Sub-Saharan Africa, including South Africa, stagnated or fell; the region accounted for less than 1 percent of world output.

Output in Eastern Europe and Central Asia fell almost 20 percent during this period, with article volume in countries of the former USSR dropping by one-third (appendix table 5-35). This sharp decline mirrors the economic and political difficulties that affected their scientific enterprise, including significant cuts in their R&D spending. In contrast, several Eastern European countries had substantial gains in output in the latter half of the 1990s.

Table 5-20
Per capita output of S&E articles, by country/economy: 1999–2001

Country/economy	Articles/1 million inhabitants
Switzerland	1,165.0
Sweden	1,139.3
Israel	1,055.2
Finland	960.5
Denmark	932.2
United Kingdom	821.9
Netherlands	800.5
Australia	794.2
United States	722.2
Norway	720.0
Singapore	590.3
France	538.6
Germany	530.5
OECD	490.3
Japan	445.6
Ireland	429.9
Spain	382.7
Italy	371.4
Taiwan	330.3
Czech Republic	241.4
South Korea	206.8
Portugal	191.3
Poland	139.9
Russia	116.4
Worldwide[a]	108.8
Bulgaria	103.7
Argentina	77.8
Chile	75.7
South Africa	55.8
Brazil	38.8
Lebanon	37.3
Mexico	31.8
Egypt	23.2
Costa Rica	22.8
Malaysia	21.9
China	14.8
Iran	13.6
Thailand	10.8
India	10.8
Kenya	8.6
Guatemala	1.5

[a] Excludes Bosnia, Taiwan, and several small countries and island countries because of lack of population data.

NOTES: Countries/economies listed in descending rank order by average of per capita output for 1999–2001. Counts based on fractional assignments (e.g., an article with two authors from different countries is counted as half an article for each country).

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Indexes; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations; population data (except Taiwan)—World Bank, *World Development Indicators 2002* (Washington, DC, 2002); Taiwan population—U.S. Central Intelligence Agency, *The World Factbook 2002* (Washington, DC, 2002).

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[42] See Arunachalam (2002). The author notes that India's world share of scientific publications has fallen while South Korea and China have rapidly increased their growth and world share of scientific articles.

Flattening of U.S. Article Output

The number of S&E articles by authors based in the United States has remained flat since 1992, even though real R&D expenditures and the number of researchers continued to rise. This trend diverged from that of most other OECD countries during this period and is a reversal from 3 prior decades of consistent growth (figure 5-32). The reasons for this development remain unknown. (See sidebar, "Exploring Recent Trends in U.S. Publications Output.")

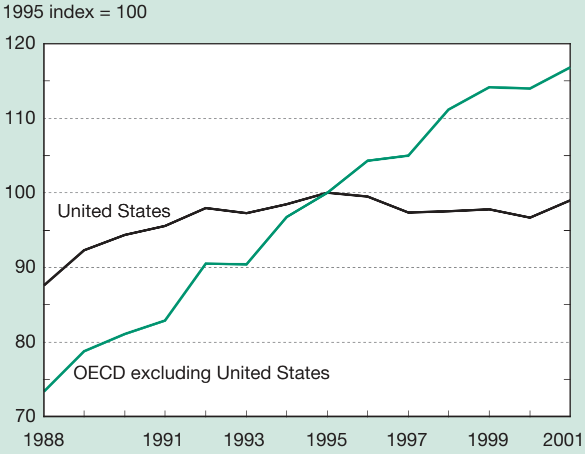
This phenomenon is not limited to the United States. Three mature industrial countries with significant article outputs—Canada, the United Kingdom, and the Netherlands—experienced a similar flattening of article output, starting in the latter half of the 1990s (figure 5-33). In addition, in most other OECD countries, increases in article output were slower in the second half of the 1990s than in the first half.

Table 5-19 shows that in most individual fields, the growth trends in U.S.-authored articles followed similar trajectories. The number of articles continued to rise into the 1990's but remained constant thereafter. Chemistry and physics articles declined after 1992, with a particularly steep drop in physics. Output in biology was stagnant over the entire 1988–2001 period. Output in the earth and space sciences increased, although the increase slowed toward the end of the period.

The growth trend in articles from the U.S. academic sector, which accounts for almost three-fourths of U.S. articles, was similar to that of overall output (figure 5-34 and appendix table 5-36). Output flattened across most individual scientific fields starting in the mid-1990s. Physics articles, however, declined significantly after 1994. The field distribution of scientific articles in the U.S. academic sector remained largely unchanged during this period (figure 5-35 and appendix table 5-36).

Article output of other sectors followed a similar growth path. In the Federal Government, output declined after 1994,

Figure 5-32
Output of S&E articles for United States and OECD: 1988–2001



OECD Organisation for Economic Co-operation and Development

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-35.

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Exploring Recent Trends in U.S. Publications Output

Publication of research results in the form of articles in peer-reviewed journals is the norm for contributing to the knowledge base in many scientific disciplines. It has become customary to track the number of peer-reviewed articles as one, albeit imperfect, indicator of research output. In recent years, international use of this and related indicators has become widespread, as countries seek to assess their relative performance.

The recent flattening in the output of U.S. science and engineering publications contrasts with continued increases in real research and development expenditures and number of researchers. The reasons for these divergent trends remain obscure. To explore what factors may be implicated in this development, the National Science Foundation is undertaking a special study that addresses the following questions:

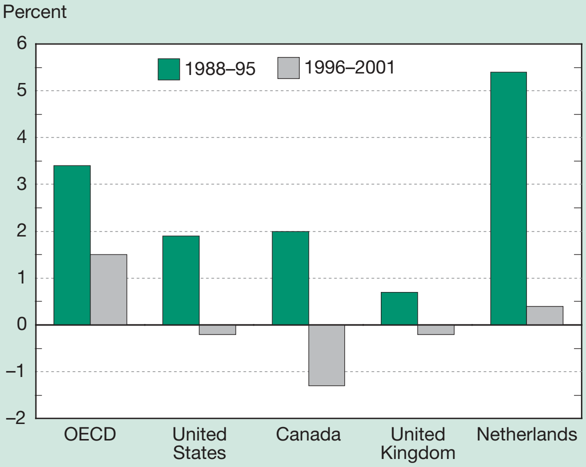
- What key trends affected the scientific publishing industry in the 1990s?
- Is the apparent change in output trends real or an artifact of the indicators used?
- What are the characteristics of the change in the trend?
- What factors may contribute to it, and what evidence exists about whether and how these factors are involved?

The project analyzes key developments in scientific publishing, with particular focus on the 1990s, to establish the broad outlines of the environment in which scientific publishing in the United States is taking place. It also includes methodological research that focuses directly on the publications themselves. This research will examine the effects of measurement approaches, journal coverage, and other technical considerations on indicators of publications output.

Work will also be undertaken to determine where in the U.S. research system these trend changes are found; what institutional, demographic, funding, or other factors may be contributing to them; and what the nature of these relationships may be. Field differences in publication patterns will be a major theme of the analysis. The results of the study are expected to be published in *Science & Engineering Indicators – 2006* and in special reports.

primarily because of a decrease in articles in the life sciences and physics. Industry output also declined during the 1990s, with significant declines in the fields of chemistry, physics, and engineering and technology. The exception to this trend was the nonprofit sector, in which article share grew during the late 1990s because of an increasing number of articles in clinical medicine.

Figure 5-33
Average growth in S&E articles for selected countries: 1988–2001



OECD Organisation for Economic Co-operation and Development

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-35.

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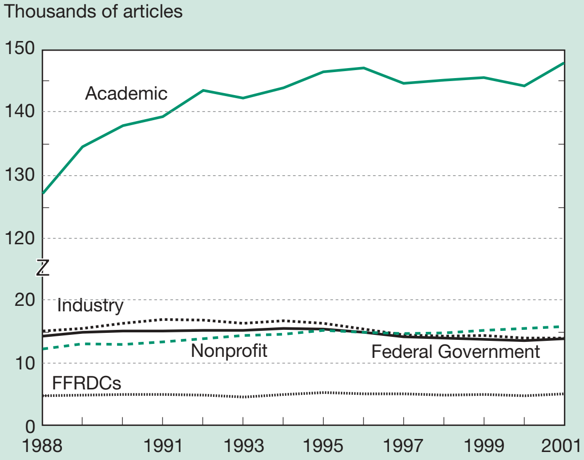
Figure 5-34
Output of S&E articles, by selected U.S. institutional sectors: 1988–2001



FFRDC federally funded research and development center

NOTES: Article counts are based on fractional assignments; for example, an article with two authors from different sectors is counted as one-half of an article for each sector. Articles with coauthors from more than one country are counted similarly.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-36.

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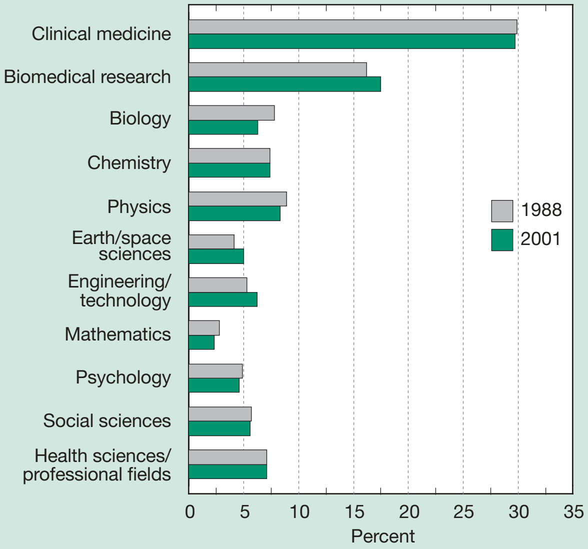
Field Distribution of Articles

The field distribution of scientific articles changed little between 1988 and 2001. The life sciences dominated the portfolio of the OECD countries, including the United States, and of Central and South America and Sub-Saharan Africa (figure 5-36 and appendix tables 5-37 and 5-38). The share of life sciences is noticeably smaller in the Middle East (excluding Israel), Eastern Europe/Central Asia, and the four emerging Asian countries, with the physical sciences and engineering and technology more dominant.

Scientific Collaboration

Coauthorship of S&E articles reveals the changing social structure of the conduct of scientific research. In most fields, articles are increasingly authored by research teams that span academic departments or institutions, cross-sectoral boundaries, or include international collaborators. Collaboration on S&E articles, as measured by articles with more than one institutional author, has increased significantly in the past 2 decades. Collaboration on scientific articles has intensified across institutional boundaries in the United States and between countries. The rise in domestic and international collaboration has been driven by several factors:

Figure 5-35
Field distribution of U.S. S&E articles from academia: 1988 and 2001



NOTES: Field classification by CHI Research, Inc. Computer sciences are included in engineering/technology.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-36.

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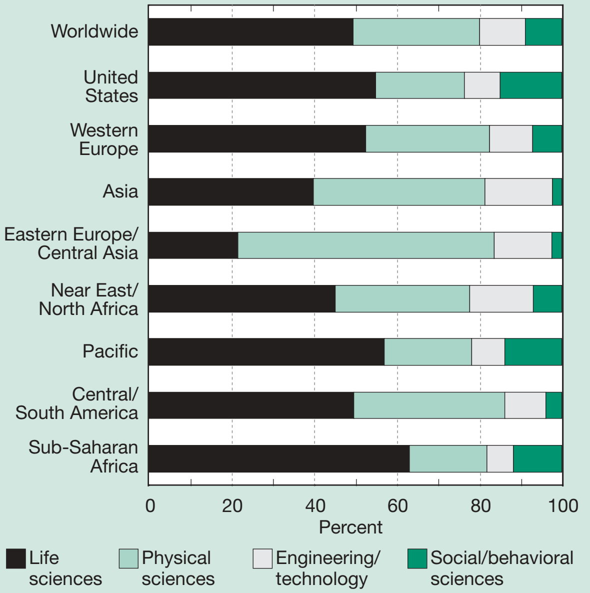
Figure 5-36
Field distribution of S&E articles, by region: 2001



NOTES: Life sciences include clinical medicine, biomedical research, and biology. Physical sciences include chemistry, physics, and earth and space sciences. Social and behavioral sciences include social sciences, psychology, health sciences, and professional fields. Computer sciences are included in engineering/technology.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-38.

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- **Scientific need.** Cutting-edge science in many fields increasingly involves a broad range of knowledge, perspectives, and techniques that extend beyond a given discipline or institution. Moreover, the scope, cost, and complexity of some of today's scientific problems, such as mapping the human genome, studying global environmental trends, or constructing an observatory in space, invite and often compel domestic and international collaboration.
- **Technological advances.** Advances in transportation and information and communications technologies have reduced geographical and cost barriers to domestic and international collaboration. Air travel and international telephone calls have become relatively inexpensive. E-mail greatly facilitates collaboration by allowing rapid exchange of information and reducing the need for frequent face-to-face meetings or telephone exchange. The increasing use of high-capacity computer networks allows researchers to exchange data files and even to conduct experiments from a distance. Improvements in software permit researchers to share research findings, conduct research online without requiring a centralized laboratory, and conduct virtual experiments.
- **Education.** Study abroad appears to contribute to growth in international collaboration.[43] Relationships established between foreign students and their teachers can form the basis of future collaboration after the students return to their native country. As an important supporting element in other factors driving collaboration, information technology greatly facilitates this type of collaboration.
- **Falling political barriers.** The end of the Cold War allowed countries to establish and/or renew political, economic, and scientific ties. It also led to the addition of new members to the world's countries.[44]
- **Government policies.** A range of nations have adopted policies to encourage scientific collaboration, motivated by the belief that collaboration maximizes and leverages their public investment in research funding, increases progress in S&T, boosts domestic capability, and/or speeds the transfer of knowledge. These policies include public R&D funding requirements to encourage or require domestic or international collaboration and formal international S&T agreements with other countries.

Collaboration Within the United States

Scientific collaboration across institutional boundaries in the United States is extensive and has continued to intensify. The share of coauthored articles increased from 48 percent of all U.S. articles in 1988 to 62 percent in 2001 (figure 5-37 and appendix tables 5-39 and 5-40). The level of institutional collaboration by field, in terms of the share of coauthored articles, was highest in clinical medicine, biomedical research, the earth and space sciences, and physics, and lowest in chemistry, psychology, the social sciences, and the professional fields (figure 5-37). According to an earlier study, these variations may reflect the nature, culture, and complexity of the research by field and the level and requirements of government funding.[45]

Government policies have reinforced collaboration by requiring or encouraging collaboration as a condition of research funding and by announcing programs targeted to encouraging cross-sectoral collaboration [e.g., between industry and universities or federally funded research and development centers (FFRDCs)]. This is particularly evident in the academic sector, where collaboration has been increasing between departments within an institution, between universities, and between universities and other sectors, including the government, industry, and the nonprofit sector.

In 2001, articles with authors from different institutional sectors (academic, industry, Federal Government, nonprofit institutions, FFRDCs, and state and local government) accounted for more than one-third of the academic sector's coauthored articles and more than three-fourths of those of the other sectors (table 5-21 and appendix tables 5-41 and

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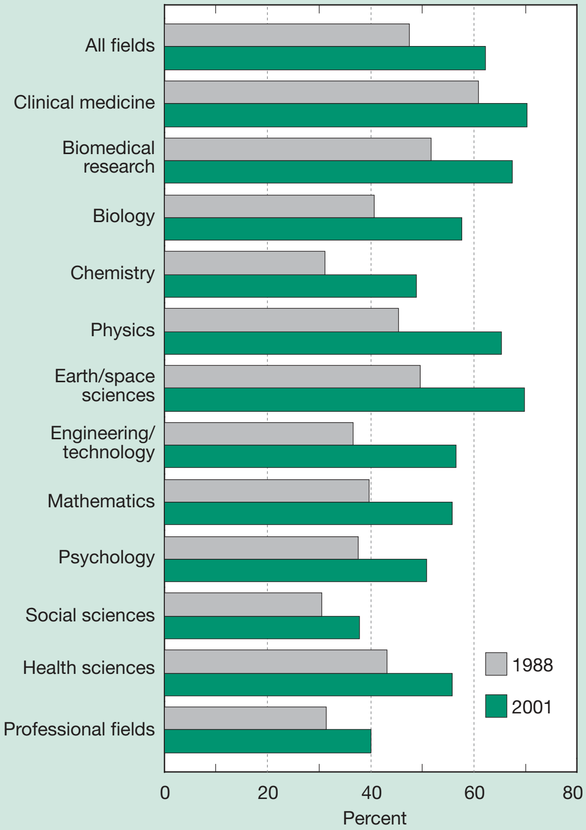
[43] See chapter 2, "Higher Education in Science and Engineering."

[44] Part of the increase reflects the creation of new countries, such as those formed from the former Soviet Union, during this period. The volume and share of international articles, however, has continued to rise since the early 1990s.

[45] See De Solla Price (1986), pages 77–79.

Figure 5-37
Extent of collaboration on U.S. S&E articles, by field: 1988 and 2001



NOTES: Number of S&E articles with multiple institutional authors, including foreign institutions, as share of total S&E articles. Field volume is in terms of whole counts, where each collaborating institutional author is assigned an entire count. Computer sciences are included in engineering/technology.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 5-39 and 5-40.

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5-42). The academic sector was at the center of cross-sectoral collaboration, represented in more than 80 percent of the articles originating in other sectors. Patterns of cross-sectoral collaboration are field specific, centered around a key sector on the basis of shares that substantially exceed the average of all articles:

- The nonprofit sector is a key collaborator with academia and FFRDCs in clinical medicine, a field in which it has a large share of article output relative to its overall share.
- Industry is a significant collaborator with academia in chemistry and partners with the Federal Government and academia in engineering and technology.
- The Federal Government is a key collaborator with academia and FFRDCs in the earth and space sciences.

International Collaboration

The international nature of science and its increasing globalization are reflected in the growth of international collaboration in scientific and technical research. Trends in international coauthorship of research articles in leading S&E journals provide a measure of the extent of international collaboration. The number of collaborative articles (i.e., those with institutional authors from more than one country) has greatly increased over the past 2 decades, and they constitute a larger proportion of all articles than in the past.

From 1988 to 2001, the total number of internationally coauthored articles more than doubled, increasing in share from 8 to 18 percent of all S&E articles. This rise has been driven by intensified collaboration among the dominant centers of S&E publishing, the United States, Western Europe, and Japan. It also reflects an increase in collaboration between these dominant centers and developing and emerging economies in Asia, Eastern Europe, the Near East, North and Sub-Saharan Africa, and Latin America. Finally, it reflects the development of an East Asian area of collaboration centered in China.

U.S. authors participate in the majority of internationally coauthored articles, and they collaborate with authors around the world. However, as other countries expanded the number and reach of their international collaborations, the U.S. share of internationally coauthored papers has fallen since the late 1980s. The extent of U.S. collaboration with scientists from other countries is shown in their growing shares of coauthorships on U.S. articles. Authors from Western European countries are well represented, and several emerging economies, notably China and South Korea, have also become major collaborators with the United States.

U.S. Role in International Scientific Collaboration. The extent of a country's influence on world scientific developments can be broadly indicated by the range of its international connections, measured here by the volume of internationally coauthored articles in which its authors participate. U.S.-based authors were represented in 44 percent of all internationally coauthored articles in 2001. In terms of number of collaborative partners, the United States collaborated with 166 of 180 countries that collaborated on any scientific article in 2001 (table 5-22 and appendix table 5-43). U.S. scientists collaborated in 18 to 42 percent of the internationally coauthored articles of most Western European countries. U.S. participation rates were higher in articles by Asian scientists, particularly those from China, the Asian newly industrialized economies (NIEs) of Hong Kong, Singapore, South Korea, and Taiwan, and the two countries with low overall rates of international collaboration, India and Japan (table 5-23 and appendix table 5-44).

With emerging and developing countries, U.S. collaboration is also significant and tends to be relatively high with countries that have significant regional output, such as Argentina, Brazil, and South Africa. The exception is Eastern Europe, where the U.S. share is generally lower than that

Table 5-21
U.S. cross-sectoral collaboration: 2001
(Percent)

Sector	All sectors	Academic	Industry	Federal Government	Nonprofit institutions	FFRDCs	State and local government
Academic	37	na	26	32	37	11	6
Industry	76	83	na	17	17	6	3
Federal Government	80	87	15	na	15	5	4
Nonprofit institutions	79	91	13	13	na	2	4
FFRDCs	80	85	14	14	7	na	0
State/local government	92	86	12	20	23	1	na

na not applicable
FFRDC federally funded research and development center

NOTES: Shares based on whole counts of publications, where each institutional author on a coauthored article is assigned a whole count. This counting methodology results in the sum of sector shares exceeding 100 percent because some coauthored articles involve collaboration across more than two sectors.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-42.

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of most other countries, ranging from 12 to 29 percent for almost all countries in this region.

The international collaborative activities of other countries generally grew more rapidly than those of the United States, resulting in an erosion of the relative U.S. share in these collaborations, although not their absolute number. The U.S. share of most countries' internationally authored papers was lower in 2001 than in 1988 (table 5-23 and appendix table 5-44). This pattern suggests that new centers of activity and collaboration are evolving outside of the United States. Among the major producers, the largest relative decline in U.S. collaboration was with Israel and Japan. These countries expanded their collaboration with many Western European countries and Russia; Japan also increased its collaboration with several Asian countries. Among emerging countries, the U.S. share in the Asian NIEs declined as these countries increased their ties with other Western European and other Asian countries, chief among these being China.

However, in an exception to this general trend, U.S. participation in China's internationally coauthored articles continued to rise, even as China's article output more than tripled in volume during the brief span from 1994 to 2001. Other exceptions included collaboration with scientists in Russia, the Czech Republic, Poland, and Ukraine. The rise in the U.S. share of these countries' international collaborations may reflect the effects of U.S. and other programs targeted to this goal. For example, several U.S. Federal agencies, including NSF, DOE, and NIH, have current or former programs to help fund collaborative research. In addition, the other organizations, including the EU, Civilian Research and Development Foundation (CRDF), and the North Atlantic Treaty Organisation (NATO), have programs that allow or encourage U.S. scientific collaboration with Eastern Europe.

Extent of International Collaboration on U.S. Scientific Articles. The degree to which other countries' scientific establishments are influential in the scientific and technical developments of the United States can be measured broadly by the role internationally coauthored articles play in the output of U.S. S&E articles. By 2001, 23 percent of all U.S. articles had at least one non-U.S. coauthor, compared with 10 percent in 1988. By field, international collaboration was highest in physics, the earth and space sciences, and mathematics, ranging from 35 to 38 percent of U.S. articles (figure 5-38). International collaboration rates were much lower in the social and behavioral sciences at about 10 percent.

The countries with the highest rates of collaboration with the United States were largely those with mature S&T systems. The top 15 collaborators with the United States included several Western European countries, Japan, Canada, China, South Korea, and Russia (table 5-24). Expansion of such ties has been particularly rapid for China, which vaulted from 14th to 7th largest collaborator during the period,[46] and South Korea, which moved from 17th to 12th. The patterns of international collaboration with the United States also appear to reflect the ties of foreign students who received advanced training in the United States (figure 5-39).[47]

International Collaboration Outside the United States

The development of scientific collaboration beyond the boundaries of mature industrial economies is illustrated by the expansion of collaborative ties among the other nations. International collaboration in the rest of the world grew significantly in terms of volume and share of internationally coauthored articles relative to all S&E articles between 1988

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[46] The addition of Hong Kong's coauthored articles in 2001, which were counted separately from China's in 1994, slightly boosted China's share. Were Hong Kong included in China in 1994, however, China's rank would have been unchanged.

[47] There is a moderately high correlation ($r^2 = 0.45$) between the number of U.S. Ph.D.s awarded by country to foreign-born students in 1992–96 and the volume of papers coauthored by the United States and those countries in 1997–2001.

Table 5-22
Breadth of international S&E collaboration, by country/economy: 1994 and 2001

Country/economy	Collaborating countries 1994	2001
Developed		
United States	154	166
France	140	152
United Kingdom	143	150
Germany	125	130
Netherlands	115	127
Italy	114	121
Canada	119	120
Spain	88	116
Switzerland	112	116
Japan	97	114
Belgium	100	112
Australia	93	106
Sweden	110	102
Denmark	83	100
Austria	73	93
Norway	64	87
Israel	71	86
Portugal	51	86
Greece	68	82
Finland	73	81
Ireland	57	71
New Zealand	55	66
Emerging/developing		
China	78	103
Brazil	85	102
India	90	101
South Africa	58	95
Mexico	69	89
Russia	89	88
Poland	73	79
South Korea	52	78
Argentina	58	76
Hungary	64	74
Czech Republic	65	72
Kenya	50	69
Thailand	59	69
Egypt	72	67
Taiwan	46	66
Chile	57	64
Indonesia	37	60
Singapore	36	57
Slovakia	51	54
Nigeria	59	52
Croatia	44	52
Pakistan	37	52
Estonia	29	47
Lebanon	19	46
Philippines	38	46
Vietnam	25	46
Uganda	31	44
Iran	20	44

NOTE: Data are number of countries that have jointly authored articles (based on institutional address) with indicated countries.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-43.

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Table 5-23
International coauthorship with United States, by country/economy: 1988, 1994, and 2001

(Percent)

Country/economy	U.S. share of coauthored articles 1988	1994	2001
Emerging/developing			
Taiwan	76	72	58
South Korea	65	65	57
Mexico	56	49	42
Turkey	33	37	41
Chile	42	36	39
Brazil	42	40	39
China	49	34	37[a]
India	37	39	37
Thailand	34	35	35
Kenya	38	36	35
Argentina	35	33	35
Philippines	46	29	33
Egypt	34	34	32
South Africa	39	33	31
Singapore	23	32	30
Hungary	27	31	29
Zimbabwe	21	31	29
Nigeria	39	23	27
Poland	24	24	27
Iran	43	39	26
Indonesia	26	34	26
Russia	na	22	24
Estonia	na	19	20
Czech Republic	na	17	20
Vietnam	na	4	16
Malaysia	23	19	14
Cuba	4	10	9
Morocco	19	14	7
Developed			
Canada	55	53	53
Israel	67	60	52
Japan	53	49	43
Australia	40	36	37
Italy	35	34	32
Switzerland	31	31	31
United Kingdom	33	31	31
Germany	33	30	30
Netherlands	32	30	30
Denmark	31	29	29
Finland	32	34	29
Sweden	37	30	27
Spain	29	27	27
Norway	31	30	26
France	29	27	26
Belgium	26	24	23
Ireland	23	25	18

na not applicable

[a] Includes articles from Hong Kong.

NOTES: Countries listed in descending order by U.S. share of all internationally coauthored articles in 2001. Article volume is on a whole-count basis (i.e., each collaborating country is assigned an entire count on international articles).

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-44.

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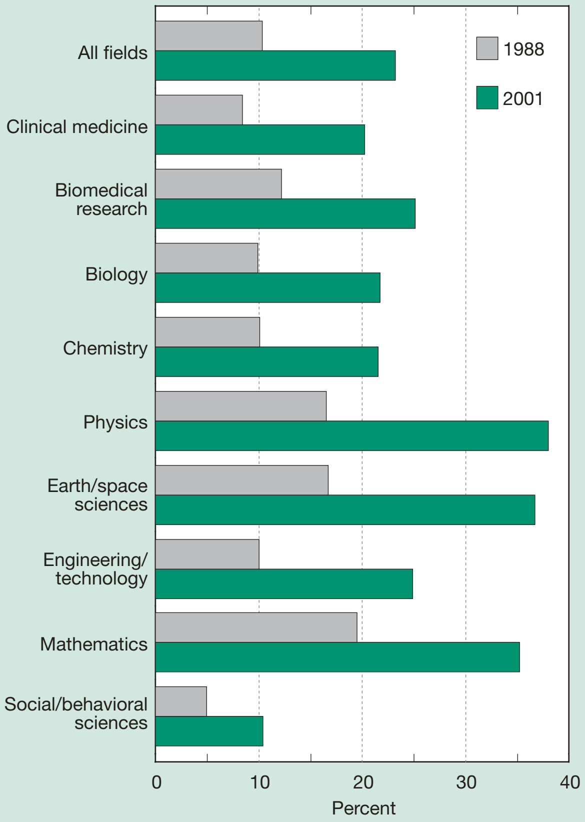
Figure 5-38
Extent of international collaboration on U.S. S&E articles, by field: 1988 and 2001



NOTES: International collaboration is the number of U.S. articles with at least one non-U.S. coauthor as a share of the total number of U.S. articles. Field volume is in whole counts, where each institutional coauthor is assigned an entire count. Social/behavioral sciences include social sciences, psychology, health sciences, and professional fields. Computer sciences are included in engineering/technology.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 5-39 and 5-40.

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and 2001. This increase was the result of an expansion in the volume of existing collaboration among countries and a substantial increase in the number of new country partnerships (figure 5-40).

In 2001, nearly 60 countries had ties to at least 50 or more other nations, compared with 43 in 1994. Emerging and developing countries generally expanded their collaborative ties more than mature science producers (table 5-22 and appendix table 5-43).[48] Although international ties greatly expanded, many countries, particularly those with smaller science establishments, tend to collaborate with relatively few developed countries.

Table 5-24
Top countries collaborating with United States on S&E articles: 1994 and 2001
(Percent of U.S. internationally authored articles)

	1994		2001	
Rank	Country	Percent	Country	Percent
1	Canada	12.6	Germany	13.5
2	United Kingdom	12.1	United Kingdom	12.9
3	Germany	12.0	Canada	11.1
4	Japan	10.0	Japan	10.2
5	France	8.8	France	8.7
6	Italy	6.7	Italy	6.9
7	Israel	4.7	China[b]	4.7
8	Switzerland	4.1	Australia	4.7
9	Netherlands	4.1	Netherlands	4.3
10	Australia	3.8	Spain	3.8
11	Sweden	3.5	Switzerland	3.8
12	Russia	3.3	South Korea	3.6
13	Spain	2.8	Russia	3.5
14	China[a]	2.1	Israel	3.5
15	Belgium	2.0	Sweden	3.4

[a] Excludes Hong Kong. Including Hong Kong would add 0.5 percentage point.
[b] Includes Hong Kong.

NOTES: Article volume is on a whole-count basis (i.e., each collaborating country is assigned an entire count on international articles). Shares are on the basis of the number of country's coauthorships as a fraction of U.S. internationally authored articles.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-44.

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In Western Europe, articles with at least one international coauthor accounted for 33 percent of all articles in 2001, up from 17 percent in 1988 (figure 5-40). Countries in this region, many of which had extensive ties during the previous decade, continued to expand their partnerships. There were 10 Western European countries with ties to 100 or more nations in 2001, a clear sign of this region's extensive scientific collaboration with other nations (table 5-22). Countries that had a particularly rapid expansion in collaborative partners included Spain, Norway, Portugal, Turkey, and Ireland; these countries also had rapidly expanding article output. Much of the high degree of international collaboration in Western Europe (as measured by the share of the countries' articles with institutional coauthors from other European countries) reflects the extensive intraregional collaboration centered on France, Germany, Italy, Spain, and the United Kingdom (appendix table 5-45). The extent of and increase in intra-European collaboration in part reflects historical ties and in part the effects of EU programs that encourage collaboration.

In Asia, the share of international articles increased from 11 percent of all articles in 1988 to 21 percent in 2001, reflecting an expansion in international coauthorship by China, India, Japan, and emerging countries such as Malaysia and Indonesia (figure 5-40). Japan, China, and India saw

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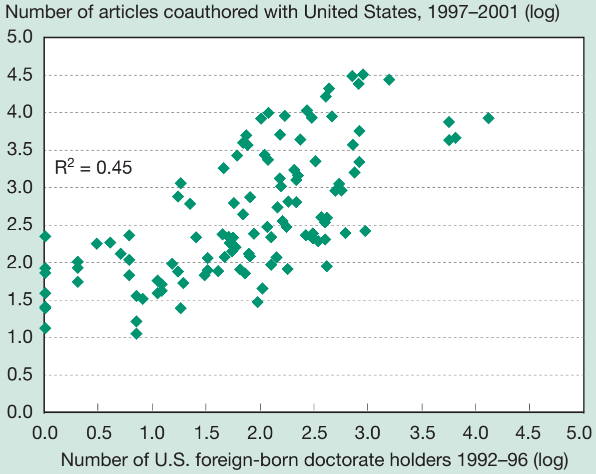
[48] Twenty-six nations have formed since 1990, primarily as a result of the breakup of the former Soviet Union, but almost all were formed before 1994. Thus, new countries are not a factor in the expansion of collaboration on scientific articles between 1994 and 2001.

Figure 5-39
Relationship of advanced training to international collaboration with United States: 1992–96 and 1997–2001



NOTE: Countries with at least 0.02 percent share of internationally coauthored articles are included. Coauthored articles are on the basis of whole counts, where each country is assigned an entire count for coauthorship on an S&E article with the United States.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc; and National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tablulations.

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their collaborative ties extend to more than 100 countries between 1994 and 2001 (table 5-22).

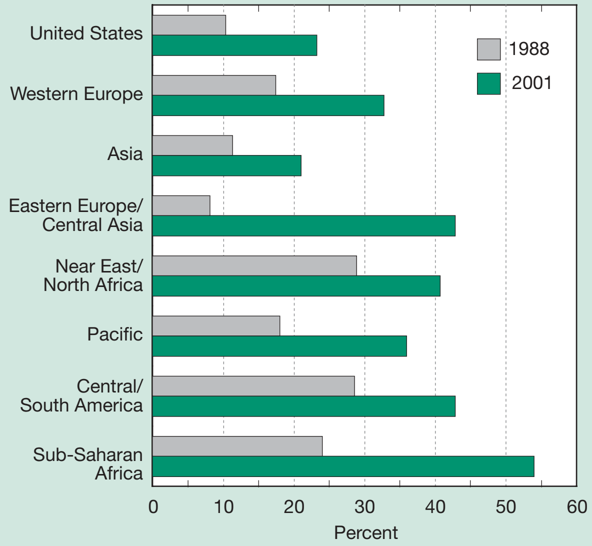
The rate of international coauthorship of the East Asian economies of China, Taiwan, and South Korea stayed constant during this period at 8–30 percent of their rapidly increasing output (appendix table 5-44). However, their collaboration expanded to a larger number of countries, primarily major science producers, as their share of U.S.-coauthored articles declined from very high levels. Greater intraregional collaboration in Asia, centered particularly on China, was also a significant factor in the increase in international collaboration for these three NIEs (appendix table 5-46).

In other emerging and developing regions, such as Central and South America, countries expanded their collaboration with Western Europe and Japan and also increased their collaboration with countries in their own region (appendix table 5-47). Intraregional collaboration in Central and South America, however, is more modest and limited than in Western Europe and Asia.

International Citation of S&E Articles

Citations in S&E articles generally credit the contribution and influence of previous research to a scientist's own research. Trends in citation patterns by region, country, scientific field, and institutional sector are indicators of the perceived influence and productivity of scientific literature

Figure 5-40
International S&E collaboration, by region: 1988 and 2001



NOTES: International collaboration is the number of articles with at least one foreign coauthor as a share of the total number of articles from the region or country. Article volume is in whole counts, where each institutional coauthor is credited with a whole count.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations

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across institutional and national boundaries.[49] Citations may also provide an indication of the access to and visibility of scientific research across national boundaries.

The trends and patterns in the citation of scientific literature by country are similar to those in the output of S&E articles. On the basis of volume, the major producers of scientific articles—the United States, Western Europe, Japan, and other OECD countries—are those whose S&E literature is most cited (table 5-25 and appendix table 5-48). In 2001, the United States' share of the world's output of cited S&E literature was 44 percent, the largest single share of any country. Collectively, the OECD countries accounted for 94 percent of the world's cited scientific literature in 2001 (table 5-25), a share that exceeded these countries' share of the world output of S&E articles (see table 5-18).

Citation of the S&E literature of the OECD countries was also high relative to these countries' share of world output of S&E articles. When the United States' share of literature cited by the rest of the world is adjusted for its share of published literature, its *relative citation index,* it is the most cited

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[49] Citations are not a straightforward measure of quality because of authors' citation of their own previous articles; authors' citation of the work of colleagues, mentors, and friends; and a possible nonlinear relationship between a country's output of publications and citations to that output.

Table 5-25
OECD share of world S&E literature cited in S&E articles: 2001

Country	Percent
All OECD	94.1
United States	43.6
United Kingdom	8.2
Japan	7.3
Germany	7.1
France	4.9
Other OECD	22.9

OECD Organisation for Economic Co-operation and Development

NOTES: Citations are references to U.S. scientific articles in journals indexed and tracked by the Institute for Scientific Information's Science Citation Index and Social Sciences Citation Index. Country shares are based on citations of articles credited to an institutional address within the country. For internationally authored articles, countries are credited the fractional contribution to the article.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-48.

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compared with other regions and second most cited country (table 5-26 and appendix tables 5-49 and 5-50). The relative citation indexes of the Western European countries, whose S&E literature is also frequently cited by the United States and other regions, especially Eastern Europe/Central Asia, are also high. Measured by relative citation index, Switzerland is the most highly cited country in the world and the top-cited country in the fields of engineering and technology (with an especially high index of 1.8) and biology and shares the top spot with the United States in biomedical research.

Table 5-26
Relative prominence of citations of S&E literature, by region: 1994 and 2001
Relative citation index

Country/region	1994	2001
United States	1.01	1.01
Western Europe	0.67	0.72
Asia	0.43	0.41
Eastern Europe/Central Asia	0.13	0.23
Near East/North Africa	0.47	0.53
Pacific	0.59	0.64
Central/South America	0.31	0.37
Sub-Saharan Africa	0.30	0.36

NOTE: Relative citation index is the frequency of citation of a country or region's scientific literature outside of its own region, adjusted for its world share of S&E articles.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-49.

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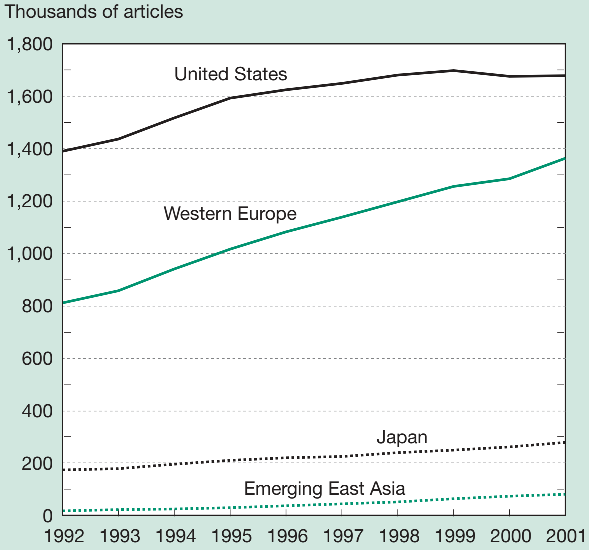
In contrast to the OECD countries, the emerging and developing countries were cited 25 to 75 percent less relative to their worldwide share of S&E articles (appendix table 5-50). In specific scientific fields, however, the relative citation indexes of a few emerging/developing countries rival those of the OECD countries. For example, Chile is the second most cited country in the earth and space sciences, and Slovenia is highly cited in mathematics.

The volume of cited scientific literature increased 43 percent between 1992 and 2001, largely driven by citation of the literature of the same regions and countries that spurred the growth in the output of scientific articles: Western Europe, Japan, and several emerging East Asian S&T centers (figure 5-41). Citation of Western European literature grew by 68 percent between 1992 and 2001, pushing this region's share of the world's cited literature from 30 to 35 percent. The increase in citation of Western European literature was led by many of same countries with dynamic growth in output of scientific articles, smaller and newer members of the EU such as Spain, Portugal, and Ireland. Citation of Japanese literature also rose substantially, increasing at roughly the same rate as Western European literature.

Citation of literature from East Asian authors in China, Singapore, South Korea, and Taiwan more than quadrupled in volume during this period, with the collective share of these countries rising from 0.7 percent of the world's cited literature in 1992 to 2.1 percent in 2001. Despite the dramatic growth in the citation volume of these countries, their

Figure 5-41
Scientific research cited in S&E articles, by selected countries/regions: 1992–2001



NOTE: Emerging East Asia consists of China, Singapore, South Korea, and Taiwan.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-48.

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relative citation indexes did not increase markedly between 1994 and 2001 (appendix table 5-50), a stability that may reflect, in part, the concentration of these countries' international ties with the United States and within Asia and/or their very rapid growth in article output.

The volume of cited U.S. scientific literature, however, flattened during the mid-1990s, with its share of cited world S&E literature falling from 52 percent in 1992 to 44 percent in 2001 (appendix table 5-48). This flattening in citation of U.S. literature occurred across almost all fields and mirrored the trend of flat U.S. output of S&E articles during this period (table 5-27). On a relative basis, however, the rate of citation of U.S. literature remained unchanged (table 5-26 and appendix tables 5-49 and 5-50).

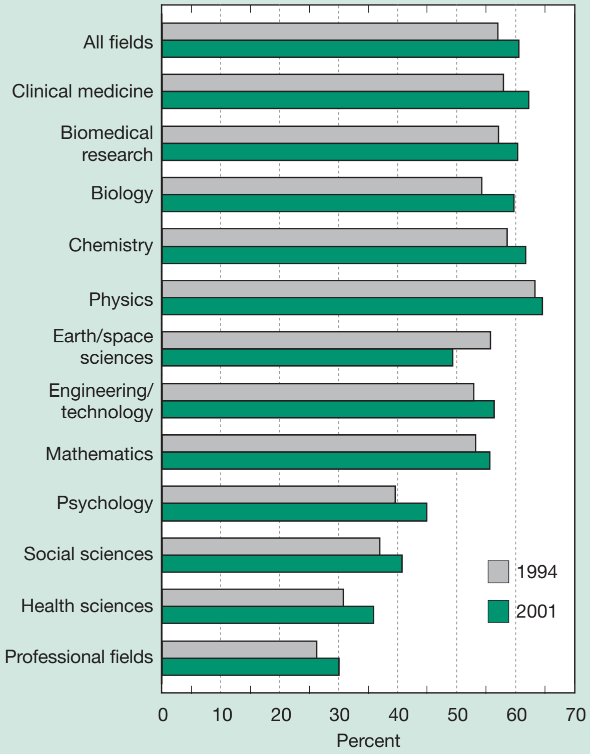
Other regions and countries also saw their citation volume increase. Between 1992 and 2001, citation of literature from Central and South America almost tripled, that from Eastern Europe/Central Asia and the Near East/North Africa rose by about one-half, and that from sub-Saharan Africa rose 17 percent. The citation volume of Indian literature, the second most widely cited in Asia, rose by 70 percent during this period.

The increase in citation volume in most regions coincided with a growing share of citations to work done outside of the author's country. The rate of citing foreign research varied by field, with high shares in physics, mathematics, and engineering and technical fields, and the lowest shares in the social and behavioral sciences (figure 5-42). Averaged across all fields, 62 percent of all citations in 2001 were to S&E literature produced outside the author's country, compared with 55 percent in 1992. This overall rate masks the United States' much lower rate of citing foreign S&E literature in comparison with the rest of the world (appendix table 5-51).

The country whose S&E literature was cited most by U.S. authors between 1994 and 2001 was the United Kingdom, followed by Germany, Japan, Canada, France, and other Western European countries (table 5-28). Worldwide, many citations of foreign S&E literature were to centers with a well-developed S&T base: the United States, Western

Figure 5-42

Foreign S&E literature cited in the world's S&E articles: 1994 and 2001



NOTES: Citations are references to articles in journals covered by the Institute for Scientific Information's Science Citation Index and Social Sciences Citation Index. Citation counts are based on a 3-year window with a 2-year lag. For example, citations for 2001 are references made in articles published in 2001 to articles published in 1997–99. Computer sciences are included in engineering and technology.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-51.

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Table 5-27

Citations of U.S. S&E articles, by field: Selected years, 1992–2001

Field	1992	1994	1996	1997	1999	2001
All fields	1,389,314	1,516,264	1,624,607	1,648,899	1,696,859	1,678,293
Clinical medicine	475,793	516,665	554,332	574,859	584,330	589,762
Biomedical research	460,148	518,304	562,361	572,122	594,596	568,328
Biology	52,535	57,825	58,649	58,130	56,981	57,899
Chemistry	88,010	96,827	105,960	105,762	110,927	109,703
Physics	137,922	141,653	138,417	131,958	125,968	120,593
Earth/space sciences	55,086	58,818	71,230	73,507	83,053	82,614
Engineering/technology	32,680	35,189	33,664	32,958	34,001	36,809
Mathematics	6,858	6,631	6,961	6,418	7,520	7,794
Social/behavorial sciences	80,282	84,353	93,032	93,187	99,481	104793

NOTES: Social/behavorial sciences include social sciences, psychology, health sciences, and professional fields. Computer sciences are included in engineering and technology. Fields counts may not sum to total due to rounding.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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Table 5-28
Countries whose S&E articles were cited most in U.S. S&E articles: 1994 and 2001

	1994		2001	
Rank	Country	Percent	Country	Percent
1	United Kingdom	17.8	United Kingdom	16.0
2	Japan	12.4	Germany	12.7
3	Germany	11.9	Japan	11.9
4	Canada	10.4	Canada	8.9
5	France	9.2	France	8.7
6	Netherlands	4.5	Italy	5.1
7	Italy	4.2	Netherlands	4.5
8	Switzerland	3.9	Australia	3.9
9	Sweden	3.7	Switzerland	3.8
10	Australia	3.7	Sweden	3.2

NOTE: Countries ranked by share of foreign S&E literature cited in U.S.-authored scientific articles.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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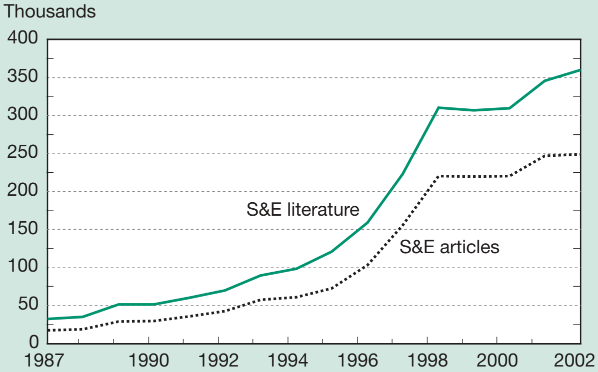
Europe, and, to some extent, Japan and the emerging East Asian countries. The exception to this is Western Europe, where about half of the citations are intraregional, consistent with the region's high degree of intraregional collaboration.

Citations in U.S. Patents to S&E Literature

U.S. patents cite previous source material to help meet the application criteria of the U.S. Patent and Trademark Office (PTO).[50] Although existing patents are the most often cited material, U.S. patents increasingly have cited scientific articles. This growth in citations of S&E literature, referenced by scientific field, technology class of the patent, and the nationality of the inventor and cited literature, provide an indicator of the link between research and practical application.[51]

The number of U.S. patent citations to S&E articles indexed in the Institute for Scientific Information's SCI rose more than 10-fold between 1987 and 2002 (figure 5-43).[52] Even as the number of patents rose rapidly, the average number of citations per U.S. patent increased more than sixfold during this period (figure 5-44).

Figure 5-43
Citations of S&E literature in U.S. patents: 1987–2002



NOTES: Citations to S&E articles are references to S&E articles in journals indexed and tracked by the Institute for Scientific Information's Science Citation Index. Citations to S&E literature are references to S&E articles within and outside of ISI's coverage and non-article material such as reports, technical notes, conference proceedings, etc. Citation counts are based on a 12-year window with a 3-year lag. For example, citations for 2000 are references made in U.S. patents issued in 2000 to articles published in 1986-97. Patent data for 2002 are preliminary and subject to change.

SOURCES: U.S. Patent and Trademark Office; Institute for Scientific Information, Science Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-52.

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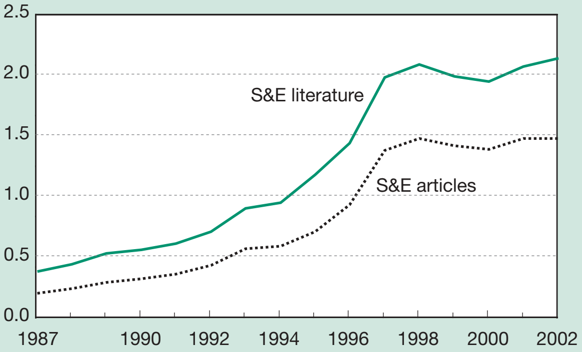
Figure 5-44
Citations of S&E literature per U.S. patent: 1987–2002



NOTES: Citations to S&E articles are references to S&E articles in journals indexed and tracked by the Institute for Scientific Information's Science Citation Index. Citations to S&E literature are references to S&E articles within and outside of ISI's coverage and non-article material such as reports, technical notes, conference proceedings, etc. Citation counts are based on a 12-year window with a 3-year lag. For example, citations for 2000 are references made in U.S. patents issued in 2000 to articles published in 1986-97. Patent data for 2002 are preliminary and subject to change.

SOURCES: U.S. Patent and Trademark Office; Institute for Scientific Information, Science Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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[50] The U.S. Patent and Trademark Office evaluates patent applications on the basis of whether the invention is useful, novel, and nonobvious. The novelty requirement leads to references to other patents, scientific journal articles, meetings, books, industrial standards, technical disclosures, etc. These references are termed *prior art.*

[51] Citation data must be interpreted with caution. The use of patenting varies by type of industry, and many citations on patent applications are to prior patents. Patenting is only one way that firms seek returns from innovation and thus reflects, in part, strategic and tactical decisions (e.g., laying the groundwork for cross-licensing arrangements). Most patents do not cover specific marketable products but might conceivably contribute in some fashion to one or more products in the future. (See Geisler 2001.)

[52] Citations are references to S&E articles in journals indexed and tracked by the Institute for Scientific Information in its Science Citation Index and Social Sciences Citation Index. Citation counts are based on articles published within a 12-year period that lagged 3 years behind the issuance of the patent. For example, citations for 2000 are references made in U.S. patents issued in 2000 to articles published in 1986–97.

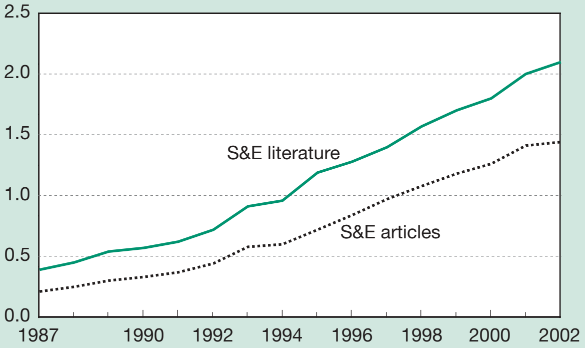
Growth of Referencing in Patents

During the past decade, the rate at which scientific papers are referenced in patents has increased rapidly. The causes of this growth are complex, but they appear to include changes made in the patent law in 1995. These changes, enacted to comply with the General Agreement on Tariffs and Trade (GATT), changed the term of patent protection from 17 years from the award date to 20 years from the filing date for applications received after June 8, 1995. Previously rejected patents refiled after this date would also be subject to the GATT rules. Applications submitted to the U.S. Patent and Trademark Office more than doubled in May and June of 1995. These applications carried an unusually large number of references to scientific material. Patents applied for in June 1995 carried three times the number of scientific references of those filed in March 1995 and six times the number of those filed in July 1995. This sudden increase in referencing affected patents in all technologies, not just those in biotechnology and pharmaceuticals, in which referencing is most extensive.

The surge in applications during this period suggests that applicants and their attorneys rushed to file their patents under the old rules, perhaps out of caution and uncertainty about the GATT rules. One source of uncertainty in the application process at the time, affecting especially biotechnology, was ambiguity about what constituted adequate written description. Because a rejected application would have to be refiled under the GATT rules, referencing a great deal of scientific material may have been a strategy to minimize the chance of rejection for inadequate written description.

Patents applied for in May and June 1995 were issued gradually over the next few years. As these patents were issued, the rate of referencing increased rapidly. However, after the last of these applications were processed, the rate of referencing fell again to levels closer to those found earlier. In fact, if these patents are eliminated from consideration, a more gradual long-term trend of increased referencing is evident (figure 5-45).

Figure 5-45
Citations of S&E literature per U.S. patent, excluding "spike" patents: 1987–2002



NOTES: Citations to S&E articles are references to S&E articles in journals indexed and tracked by the Institute for Scientific Information's Science Citation Index. Citations to S&E literature are references to S&E articles within and outside of ISI's coverage and non-article material such as reports, technical notes, conference proceedings, etc. Citation counts are based on a 12-year window with a 3-year lag. For example, citations for 2000 are references made in U.S. patents issued in 2000 to articles published in 1986-97. "Spike" patents are those with an application date of May–June 1995. Patent data for 2002 are preliminary and subject to change.

SOURCES: U.S. Patent and Trademark Office; Institute for Scientific Information, Science Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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The rapid growth of article citations in patents throughout much of the past decade was centered in huge increases in the life science fields of biomedical research and clinical medicine. Between 1995 and 2002, these fields accounted for 75 percent of the increase in total patent citation volume, and their share increased from 61 to 70 percent (appendix table 5-52).

The growth of citations of scientific research in patents attests to the increasing link between research and practical applications. The growth in citations has been driven, in part, by increased patenting of research-driven products and processes, primarily in the life sciences.[53] In addition, changes in practices and procedures in the U.S. PTO may have increased the incentive for and ease of citing scientific literature. (See sidebar, "Growth of Referencing in Patents.")

The bulk of U.S. patents citing scientific literature were issued to U.S. inventors, who accounted for 65 percent of these patents in 2001, a share that has been disproportionately higher than the U.S. inventor share of all U.S. patents since the past decade. Other key inventor regions and countries of U.S. patents that cite scientific literature are Western Europe (17 percent), including France (3 percent), Germany (5 percent), and the United Kingdom (3 percent); Japan (11 percent); emerging East Asia (2 percent); and Canada (3 percent) (table 5-29).

Examination of the share of cited literature in the United States, Western Europe, and Asia, adjusted for their respective world output share of scientific literature (relative citation index) and excluding citation of literature from the inventor's own country or region, suggests that inventors outside the United States, primarily those from Western Europe and Asia, frequently cite U.S. scientific literature (table 5-30). This is comparable to the high rate of citation of U.S. scientific literature by scientists in these regions. In addition, Asian physics articles are highly cited by inventors outside of Asia.

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[53] See discussion in following section, "Patents Awarded to U.S. Universities."

Table 5-29

U.S. patents that cite S&E literature, by nationality of inventor: 1990, 1996, and 2001

	1990 U.S. patents		1996 U.S. patents		2001 U.S. patents	
	Total	Citing S&E literature	Total	Citing S&E literature	Total	Citing S&E literature
	Number					
U.S. patents	90,379	6,367	109,687	12,894	166,039	21,155
Nationality of inventor	Percent distribution					
Worldwide	100.0	100.0	100.0	100.0	100.0	100.0
North America	54.5	64.9	57.6	66.8	55.0	68.1
Canada	2.1	1.7	2.0	2.0	2.2	2.6
Mexico	0.0	0.1	0.0	0.1	0.0	0.0
United States	52.4	63.1	55.5	64.7	52.8	65.4
Western Europe	21.1	18.3	16.4	15.5	18.1	16.8
France	3.2	3.0	2.6	2.7	2.4	2.5
Germany	8.4	6.1	6.2	4.5	6.8	4.8
Italy	1.4	0.8	1.1	0.8	1.0	0.9
Netherlands	1.1	1.3	0.7	0.8	0.8	0.9
Sweden	0.8	0.4	0.8	0.7	1.0	0.9
Switzerland	1.4	1.7	1.1	0.9	0.9	1.1
United Kingdom	3.1	3.7	2.3	3.1	3.2	3.3
Other	1.6	1.3	1.6	1.9	2.0	2.3
Asia	22.8	15.6	24.3	15.9	25.9	12.7
Japan	21.6	15.2	21.0	14.7	20.0	10.6
Emerging East Asia	1.2	0.3	3.3	1.1	5.8	1.8
Other	0.0	0.1	0.0	0.1	0.1	0.3
Other regions/countries	1.6	1.3	1.7	1.8	1.6	2.4

NOTES: Emerging East Asia consists of China, Hong Kong, Singapore, South Korea, and Taiwan. The number of U.S. patents and nationality of inventor are based on U.S. patents that reference S&E articles in journals classified and tracked by the Institute of Scientific Information's Science Citation Index. Percents may not sum to 100 because of rounding.

SOURCES: U.S. Patent and Trademark Office; Institute for Scientific Information, Science Citation Index; CHI Research, Inc.; National Science Foundation, Division of Science Resources Statistics, special tabulations.

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U.S. patents most commonly cite articles authored within the academic sector, primarily the life science fields of clinical medicine and biomedical research.[54] In 2002, the U.S. academic sector accounted for 61 percent of total citations, with almost three-fourths of these citations to clinical medicine and biomedical research (appendix table 5-53). The U.S. academic sector also had a strong presence in physics and engineering and technology, accounting for about half the citations in these fields. Between 1995 and 2002, the academic sector share increased in physics (from 40 to 51 percent) and engineering and technology (from 44 to 49 percent) coinciding with stagnating output of articles authored within the industrial sector. Industry was the next most widely cited sector (19 percent share), with articles in the fields of physics and engineering and technology prominently represented (38 and 42 percent, respectively).

The life sciences, particularly biomedical research and clinical medicine, dominated nearly every sector, with from 67 to more than 90 percent of all citations (appendix table 5-53). This included sectors that had prominent citation shares in the physical sciences earlier in the decade (industry and FFRDCs). They experienced significant declines in citations of articles in these fields, whereas their share of life sciences citations grew significantly.

Patents Awarded to U.S. Universities

The results of academic S&E research increasingly extend beyond articles in S&E journals to patent protection of research-derived inventions.[55] Patents are an indicator of the efforts of academic institutions to protect the intellectual property of their inventions, technology transfer,[56] and industry-university collaboration. The rise of patents received by U.S. universities attests to the increasingly important role of academic institutions in creating and supporting knowledge-based industries closely linked to scientific research.

Patenting by academic institutions has markedly increased over the past 3 decades, rising from about 250–350 patents annually in the 1970s to more than 3,200 patents in

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[54] U.S. performer data is restricted to U.S. citations of U.S. literature in the Institute for Scientific Information journal set.

[55] Research articles also are increasingly cited in patents, attesting to the close relationship of some basic academic research to potential commercial application. See the previous section, "Citations in U.S. Patents to S&E Literature."

[56] Other means of technology transfer are industry hiring of students and faculty, consulting relationships between faculty and industries, formation of firms by students or faculty, scientific publications, presentation at conferences, and informal communications between industrial and academic researchers.

Table 5-30
Citation of S&E literature in U.S. patents relative to share of S&E literature, by selected field and country/region: 2002
Relative citation index

Field and country/region of citing inventor	United States	Western Europe	Asia
All fields	1.23	0.69	0.64
Clinical medicine	1.19	0.69	0.65
Biomedical research	1.30	0.65	0.50
Chemistry	1.59	0.72	0.55
Physics	1.25	0.55	1.05
Engineering/technology	1.15	0.71	0.69

NOTES: Relative citation index is the frequency of citation of a country or region's S&E literature by U.S. patents, adjusted for its world share of S&E articles. Citations of the country's own literature are excluded. An index of 1.00 would indicate that the region's share of cited literature was equal to its world share of S&E literature. An index greater or less than 1.00 would indicate that the region was cited relatively more or less frequently than indicated by its share of world S&E literature. Citations are references to S&E articles in journals indexed and tracked by the Institute for Scientific Information's Science Citation Index and Social Sciences Citation Index. Citation counts are based on a 6-year window with a 2-year lag, i.e., citations for 2002 are references made in U.S. patents issued in 2002 to articles published in 1995–2000. Scientific field is determined by CHI's classification of the journal. Computer sciences are included in engineering and technology. Patent data for 2002 are preliminary and subject to change.

SOURCES: U.S. Patent and Trademark Office; Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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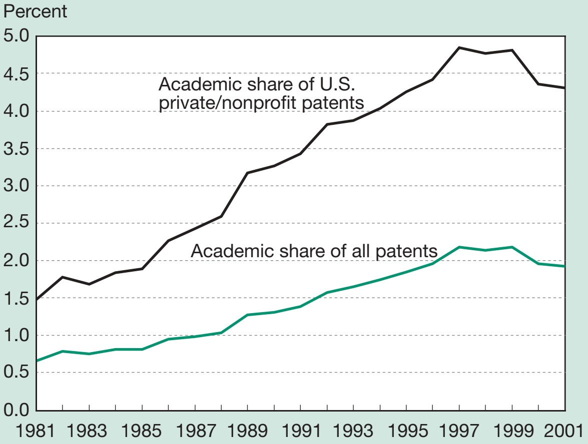
Figure 5-46
Significance of U.S academic patenting activity: 1981–2001



NOTES: Patents issued by U.S. Patent and Trademark Office to U.S. universities and corporations. U.S. private/nonprofit sector includes U.S. corporations (which are issued the bulk of patents in this category), nonprofits, small businesses, and educational institutions. All patents include U.S. patents issued to U.S. and non-U.S. organizations and individual inventors.

SOURCES: U.S. Patent and Trademark Office (USPTO), *Technology Assessment and Forecast Report: U.S. Colleges and Universities, Utility Patent Grants, 1969–2001* (Washington, DC, 2001); and USPTO, special tabulations.

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2001 (appendix table 5-54; see also NSB 1996, appendix table 5-42). The share of academic patents has also risen significantly, even as growth in all U.S. patents increased rapidly during this period. For example, U.S. academic institutions accounted for more than 4 percent of patents granted to the U.S. private and nonprofit sectors in 2001, compared with less than 1.5 percent in 1981. The share, however, was down slightly from a peak of almost 5 percent during 1997–99 (figure 5-46).

During this period, the number of academic institutions receiving patents increased rapidly, nearly doubling in the 1980s to more than 150 institutions and continuing to grow to reach 190 institutions in 2001 (appendix table 5-54).[57] Both public and private institutions participated in this rise.

Despite the increase in institutions receiving patents, the distribution of patenting activity has remained highly concentrated among a few major research universities. The top 25 recipients accounted for more than 50 percent of all academic patents in 2001, a share that has remained constant for 2 decades. These institutions also account for a disproportionate share (40 percent in 2001) of all R&D expenditures by academic patenting institutions. Including the next 75 largest recipients increases the share to more than 90 percent of patents granted to all institutions in 2001 and much of the 1990s. Many smaller universities and colleges began to receive patents in the 1980s, which pushed the large institutions' share as low as 82 percent, but the trend reversed in the 1990s (appendix table 5-54). Several factors appear to have driven the rise in academic patenting:

- **The Bayh-Dole University and Small Business Patent Act.** Passed in 1980, this law[58] permitted government grantees and contractors to retain title to inventions resulting from federally supported R&D and encouraged the licensing of such inventions to industry. Although some Federal agencies permitted universities to retain title before Bayh-Dole, this law established a uniform government-wide policy and process for academic patenting.
- **Emerging and Maturing Research-Based Industries**. During the 1990s, industries emerged and matured that used commercial applications derived from "use-oriented" basic research in life sciences fields such as molecular biology and genomics (Stokes 1997).

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[57] The institution count is a conservative estimate because several university systems are counted as one institution, medical schools are often counted with their home institution, and universities are credited for patents on the basis of being the first-name assignee on the patent, which excludes patents where they share credit with another first-name assignee. Varying and changing university practices in assigning patents, such as to board of regents, individual campuses, or entities with or without affiliation to the university, also contribute to the lack of precision in the estimate. The data presented here have been aggregated consistently by the U.S. Patent and Trademark Office since 1982.

[58] The Bayh-Dole Act of 1980 (Public Law 96-517) allows researchers or universities financed partially or completely by Federal funding to own their inventions.

- **Strengthening of Patent Protection.** Changes in the U.S. patent regime strengthened overall patent and copyright protection and encouraged the patenting of biomedical and life sciences technology. The creation of the Court of Appeals of the Federal Circuit to handle patent infringement cases was one factor in the strengthening of overall patent protection. The Supreme Court's landmark 1980 ruling in *Diamond* v. *Chakrabarty,* which allowed patentability of genetically modified life forms, also may have been a major stimulus behind the recent rapid increases.

The growth in academic patents occurred primarily in the life sciences and biotechnology (Huttner 1999). Patents in two technology areas or "utility classes," both with presumed biomedical relevance, accounted for 39 percent of the academic total in 2001, up from less than a fourth in the early 1980s. The class that experienced the fastest growth—chemistry, molecular biology, and microbiology—increased its share from 8 percent to 21 percent during this period (figure 5-47).

A survey by the Association of University Technology Managers (AUTM), which tracks several indicators of academic patenting, licensing, and related practices, attests to the expansion of patenting and related activities by universities (table 5-31). The number of new patent applications more than quadrupled between FYs 1991 and 2001,[59] indicating the growing effort and increasing success of universities obtaining patent protection for their technology.

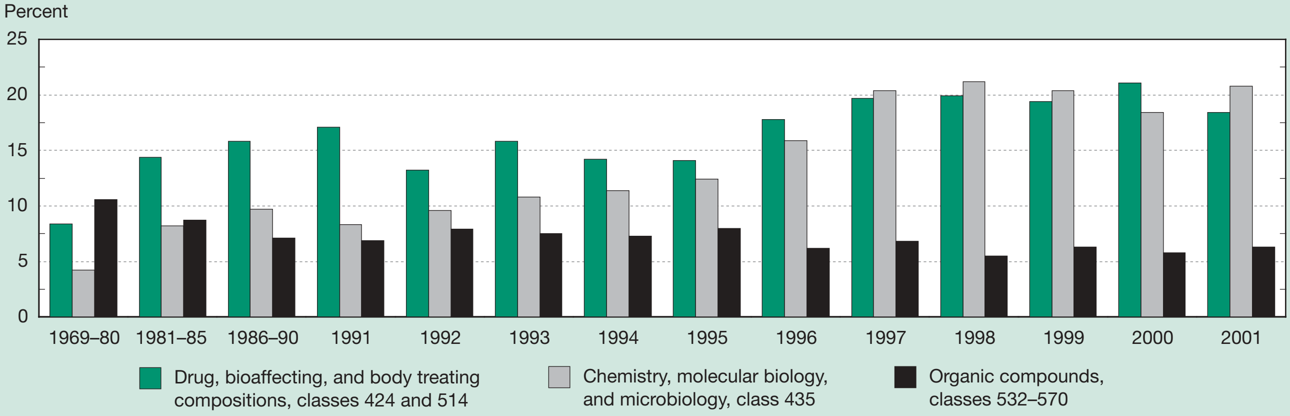
Two indicators related to patents—invention disclosures and new licenses and options—provide a broader picture of university efforts to exploit their technology. Invention disclosures, which describe the prospective invention and are submitted before a patent application or negotiation of a licensing agreement, rose sharply during this period. New licenses and options, indicating the commercialization of university-developed technology, also rose by more than half since FY 1996.

Obtaining patent protection does not always precede negotiation of a licensing agreement, underscoring the embryonic nature of university-developed technology. According to a recent survey of more than 60 major research universities, 76 percent of respondents reported that they "rarely" or "sometimes" had patent or copyright protection at the time of negotiating the licensing agreement, whereas 25 percent responded "often" or "almost always" (Thursby et al. 2001).[60] In addition, most inventions were at a very early stage of development when the licensing agreement was negotiated, and nearly half the respondents characterized their inventions as a proof of concept rather than a prototype (table 5-32).

The majority of licenses and options (66 percent) are conducted with small companies (existing companies or startups), most likely influenced by the Bayh-Dole Act's mandate that universities give preference to small businesses (figure 5-48). In cases of unproven or very risky technology, universities often opt to make an arrangement with a startup company because existing companies may be unwilling to take on the risk. Faculty involvement in startups may also play a key role in this form of alliance. The majority of licenses granted to small companies and startups are exclusive, that is, they do not allow the technology to be commercialized by other companies.

With the steady increase of revenue-generating licenses and options, income to universities from patenting and licenses has grown substantially over the past decade, reaching more than $850 million in FY 2001—more than half

Figure 5-47
Academic patents in three largest academic utility classes: 1969–2001



SOURCES: U.S. Patent and Trademark Office (USPTO), *Technology Assessment and Forecast Report: U.S. Colleges and Universities, Utility Patent Grants, 1969–2001* (Washington, DC, 2001); and USPTO, special tabulations.

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[59] Universities report data to AUTM on a fiscal-year basis, which varies across institutions.

[60] Sum exceeds 100 percent because of rounding.

Table 5-31
Academic patenting and licensing activities: 1991–2001

Indicator of activity	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	Number										
Academic institutions reporting	98	98	117	120	127	131	132	132	139	142	139
	Millions of dollars										
Net royalties	NA	NA	195.0	217.4	239.1	290.1	391.1	517.3	583.0	1,012.0	753.9
Gross royalties	130.0	172.4	242.3	265.9	299.1	365.2	482.8	613.6	675.5	1,108.9[a]	868.3
Royalties paid to others	NA	NA	19.5	20.8	25.6	28.6	36.2	36.7	34.5	32.7	41.0
Unreimbursed legal fees expended	19.3	22.2	27.8	27.7	34.4	46.5	55.5	59.6	58.0	64.2	73.4
New research funding from licenses[b]	NA	NA	NA	106.3	112.5	155.7	136.2	126.9	149.0	184.0	NA
	Number										
Invention disclosures received	4,880	5,700	6,598	6,697	7,427	8,119	9,051	9,555	10,052	10,802	11,259
New U.S. patent applications filed	1,335	1,608	1,993	2,015	2,373	2,734	3,644	4,140	4,871	5,623	5,784
U.S. patents granted	NA	NA	1,307	1,596	1,550	1,776	2,239	2,681	3,079	3,272	3,179
Startup companies formed	NA	NA	NA	175	169	184	258	279	275	368	402
Revenue-generating licenses and options	2,210	2,809	3,413	3,560	4,272	4,958	5,659	6,006	6,663	7,562	7,715
New licenses and options executed	1,079	1,461	1,737	2,049	2,142	2,209	2,707	3,078	3,295	3,569	3,300
Equity licenses and options	NA	NA	NA	NA	99	113	203	210	181	296	NA
	Percent[c]										
Sponsored research funds	65	68	75	76	78	81	82	83	82	86	84
Federal research funds	79	82	85	85	85	89	90	90	90	92	92

NA not available

[a] Includes one-time payments of equity cash in and funds received from settlement of a patent infringement suit.
[b] Directly related to a license or option agreement.
[c] Of national academic total represented by number of academic institutions reporting.

SOURCE: Association of University Technology Managers, AUTM Licensing Survey (Norwalk, CT, various years).

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Table 5-32
Stage of development of licensed inventions by U.S. universities: 1998
(Percent)

Stage of development	Invention disclosures
Proof of concept but no prototype	45.1
Prototype available but only lab scale	37.2
Some animal data available	26.7
Some clinical data available	9.5
Manufacturing feasibility known	15.3
Ready for practical commercial use	12.3

NOTES: Survey of patenting and licensing offices at 62 U.S. research universities. Sum of shares exceeds 100 percent because some respondents indicated more than one stage of development.

SOURCE: J. Thursby, R. Jensen, and M. Thursby, Objectives, characteristics and outcomes of university licensing: A survey of major U.S. universities, *Journal of Technology Transfer* 26:59–72, 2001.

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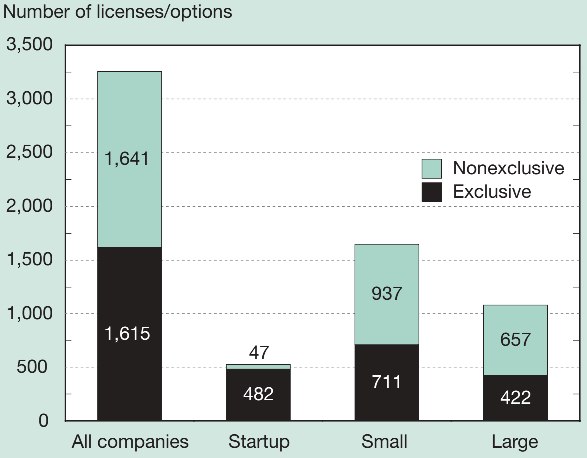
Figure 5-48
Characteristics of licenses and options executed by U.S. universities: 2000



NOTES: Exclusive agreements do not allow sharing or marketing of the technology to other companies, whereas it is permitted under nonexclusive agreements.

SOURCE: Association of University Technology Managers, AUTM Licensing Survey: FY 2000 (Norwalk, CT, 2002).

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the FY 1996 level.[61] Licensing income, however, is only a fraction of overall academic research spending, amounting to less than 4 percent in FY 2001.[62]

The 1999 AUTM survey found that about half of universities' royalties were concentrated in technology related to the life sciences. The survey categorized one-third of the remaining royalties as "not classified" and the remainder as being in the physical sciences, which appears to include engineering. Licensing income is also highly concentrated among a few universities and blockbuster patents. For example, the 2000 AUTM survey found that less than 1 percent of active licenses generated more than $1 million in income in FY 2000, a figure that includes licenses held by U.S. universities and hospitals, Canadian institutions, and patent management firms.

Because data on costs are not available, it is unclear whether universities break even or profit from their technology transfer activities. Gross revenue is allocated among the university, the inventor (who typically receives a 30–50 percent share), and costs such as patent and license management fees, which can be considerable (Sampat 2002).[63] One study estimated that 58 percent of universities surveyed made a profit on their patenting and licensing activities in 1996 (Trune and Goslin 2000).

University-industry collaboration and successful commercialization of academic research in the United States contributed to the rapid transformation of new and often basic knowledge into industrial innovations, including new products, processes, and services. Other nations, seeing these benefits, are endeavoring to import these and related practices in an effort to strengthen innovation. (See sidebar, "Academic Patenting and Licensing in Other Countries"). In the United States, however, scholars and policymakers are debating whether academic patenting and related activities led to unintended or potentially harmful effects. (See sidebar, "Debate Over Academic Patenting in the United States.")

Academic Patenting and Licensing in Other Countries

Beginning in the mid-1990s, several countries, particularly members of the Organisation for Economic Co-operation and Development (OECD), sought to encourage and increase commercialization of technology developed at universities and other publicly supported research institutions (table 5-33). The focus has been on clarifying and strengthening ownership and exploitation of an institution's intellectual property and on granting ownership of intellectual property to universities and other public research organizations (PROs) in countries where the inventor or government was the owner. The justification for these legal and policy changes is that institutional ownership provides greater legal certainty, lowers transaction costs, and fosters more formal and efficient channels for technology transfer as compared with ownership by the government or the inventor (OECD 2002). Changes in intellectual property protection of academic institutions were through a variety of means, including reforming national patent policies, employment law, and research funding regulation and clarifying policy and administrative procedures of technology license offices.

The motivation for consideration and change of these countries' regulations and policies is due to a variety of factors (OECD 2002; Mowery and Sampat 2002):

- **Emulation of the United States.** Many countries believe that the United States has been very successful at commercializing its university technology, especially following the passage of the Bayh-Dole Act, which they consider a key factor in allowing the United States to benefit economically from its scientific research through encouraging and speeding up the commercialization of university inventions. This is especially true of European countries that would like to create indigenous science-based industries and believe that the level of commercialization from their public R&D is inadequate.
- **Exploitation of Inventions Developed From Publicly Funded Research.** There is concern that current regulations and practices limit and slow the commercialization of technology developed from publicly funded research. Countries would like a greater commercial return from their investments in public scientific research and believe that strengthening and clarifying policies toward licensing and patenting will encourage and speed up commercialization.
- **Generation of Licensing Revenues.** Countries believe an increase in patenting and licensing by universities will increase revenue from licensing technology, which could support university technology activities or university research. Some countries, however, acknowledged that licensing offices lose money on their operations, and are considering subsidizing their operations with public funding
- **Formation of Spinoff Companies.** Countries believe that commercialization of university-developed tech-

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[61] Licensing income for 2000 was boosted by several one-time payments, including a $200 million settlement of a patent infringement case, and by several institutions' cashing in of their equity held in licensee companies.

[62] See *Academic Research and Development Expenditures: Fiscal Year 2001* (NSF/SRS 2003). This is a rough estimate because of the lack of data on the R&D expenditures of a few smaller institutions.

[63] Thursby et al. (2001) report that universities allocate an average of 40 percent of net income to the inventors, 16 percent to the inventor's department or school (often returned to the inventor's laboratory), 26 percent to central administrations, and 11 percent to technology transfer offices, with the remainder allocated to "other."

nology could yield formation of startup companies. Forming spinoff companies is viewed as desirable for creating new high-technology or science-based jobs and industries, fostering entrepreneurial skills and culture, and increasing competition among existing firms.

- **Promotion of International Scientific Collaboration.** The EU countries, in particular, are concerned that differing national laws and policies, particularly ownership of university technology, inhibit scientific collaboration within the EU by raising transaction costs due to legal complications and uncertainty.

The OECD conducted a survey in 2001 of member countries' technology transfer offices and examined national laws and regulations. The survey found that in countries that enacted legislation, awareness of and support for technology transfer increased among the major stakeholders, although relatively little growth in patenting, licensing, or spinoffs occurred. In addition, most licensing of technology from universities and public research organizations is based on nonpatentable inventions. These findings raise the question of whether specific features of the U.S. education, research, and legal systems play a key part in the commercialization of the results of academic research and development in the United States.

Table 5-33
Ownership of academic intellectual property in OECD countries: 2003

	Owner of invention			
Country	University	Faculty	Government	Status/recent initiatives
Australia	x	na	na	
Austria	x	na	na	
Belgium	x	na	na	
Canada[a]	x	x	na	
Denmark	x	na	na	
Finland	na	x	na	Consideration of legislation in 2003 to restrict faculty's right to retain ownership of publicly funded research.
France	x	na	na	
Germany	x	na	na	Debate during 2001 over awarding ownership to universities.
Iceland	na	x	na	
Ireland	x	na	na	
Italy	na	x	na	Legislation passed in 2001 to give ownership rights to researchers. Legislation introduced in 2002 to grant ownership to universities and create technology transfer offices.
Japan[b]	na	x	o	Private technology transfer offices authorized in 1998.
Mexico	x	na	na	
Netherlands	x	na	na	
Norway	na	x	na	Legislation passed in 2003 to allow universities to retain ownership of publicly funded research.
Poland	x	na	na	
South Korea	x	na	na	
Sweden	na	x	na	Recent debate and consideration of legislation to allow universities to retain ownership of publicly funded research.
United Kingdom	x	o	na	Universities, rather than government, given rights to faculty inventions in 1985.
United States[c]	x	o	o	

x legal basis or most common practice
o allowed by law/rule but less common
na not applicable

[a] Ownership of intellectual property funded by institutional funds varies, but publicly funded intellectual property belongs to institution performing research.
[b] President of the national university or interuniversity institution determines right to ownership of invention by faculty member, based on discussions by invention committee.
[c] Universities have first right to elect title to inventions resulting from federally funded research. Federal Government may claim title if university does not. In certain cases, inventor may retain rights with agreement of university/Federal partner and Government.

SOURCES: Organisation for Economic Co-operation and Development, *OECD Questionnaire on the Patenting and Licensing Activities of PRO's* (Paris, 2002); and D. C. Mowery and B. N. Sampat, International emulation of Bayh-Dole: Rash or rational? Paper presented at American Association for the Advancement of Science symposium on International Trends in the Transfer of Academic Research, Boston, February 2002.

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Debate Over Academic Patenting in the United States

Scholars and policymakers expressed concern that the increase of patenting by universities may be having unintended and possibly harmful effects on universities, faculty, and the quality and direction of academic research. These concerns include:

- **University Portfolio and Mission.** Universities may be emphasizing or diverting resources toward research areas with commercial potential. Faculty who have relationships with existing firms or are involved in spinoff firms may have a conflict of interest or divert their efforts from their other research or teaching activities. This diversion of effort and resources away from noncommercial areas of research may harm or slow progress in these areas and may erode the widely held precept that universities promote knowledge for knowledge's sake.
- **Dissemination of Knowledge.** Licensing agreements often contain clauses that restrict or delay publication of research results or require researchers to obtain approval or pay costs for using their technology in upstream applications. In addition, researchers in these fields may restrict or withhold their results to maintain a competitive advantage. As a result, research progress in these fields may be hampered or slowed, which may be a critical concern in health or medical applications. In a broader sense, the concern is that withholding knowledge may erode the scientific norm of publicizing research results.
- **Technology Transfer Costs.** The costs of setting up, maintaining, and administering technology transfer activities are considerable, and evidence suggests that many universities do not make a profit on these activities. For example, patent litigation, which can be very costly and time consuming, has been increasing with the rise in university patents. The cost of technology transfer raises the question of whether the monetary and nonmonetary benefits of technology transfer outweigh the costs, or whether universities would obtain a higher return from other activities.
- **Commercialization of Technology.** The popularity of exclusive licensing agreements in university-licensed technology has raised concerns that this type of agreement results in higher costs to consumers and a slower pace of innovation and adoption of the technology. Proponents of exclusive agreements contend that exclusive licensing agreements are necessary to compensate for the risk of commercializing unproven and embryonic university technology and that the concerns of slower innovation and adoption are not warranted.

There is also debate about whether patenting of academic research results is appropriate or necessary. Critics argue that patenting is neither appropriate nor necessary for most research results, given their embryonic nature, and that transfer of university technology would occur in the absence of patenting.

Conclusion

Strengths and challenges characterize the position of academic R&D in the United States at the beginning of the 21st century. Its graduate education, linked intimately to the conduct of research, is regarded as a model by other countries and attracts large numbers of foreign students, many of whom stay after graduation. Funding of academic R&D continues to expand rapidly, and universities perform nearly half the basic research nationwide. U.S. academic scientists and engineers are collaborating extensively with colleagues in other sectors and, increasingly, with international colleagues: in 2001, one U.S. journal article in four had at least one international coauthor. Academic patenting and licensing continue to increase, and academic and other S&E articles are increasingly cited in patents, attesting to the usefulness of academic research in producing economic benefits. Academic licensing and option revenues are growing, as are spinoff companies, and universities are increasingly moving into equity positions to maximize their economic returns.

However, there are challenges to be faced and trends that bear watching. The Federal Government's role in funding academic R&D is declining. Research-performing universities increased their own funds, which now account for one-fifth of the total, but are facing financial pressures. Industry support has grown, but less than might be surmised, given the close relationship between R&D and industrial innovation. Industry support accounted for less than 7 percent of the total in 2001. Spending on research equipment as a share of all R&D expenditures declined to less than 5 percent by 2001, a trend worthy of attention.

Academic employment has undergone a long-term shift toward greater use of nonfaculty appointments, both postdocs and other positions. A researcher pool has grown independent of growth in the faculty ranks. These developments accelerated during the latter half of the 1990s, when both retirements and new hires were beginning to rise. This raises the question of how these related trends will develop in the future, when retirements are expected to further accelerate.

Another aspect of this issue is the level of foreign participation in the academic enterprise. Academia has been able to attract many talented foreign-born scientists and engineers, and the nation has benefited from their contributions. However, as the percentage of foreign-born degree holders approaches half the total in some fields, attention shifts to degree holders who are U.S. citizens. Among those, white males were earning a declining number of S&E doctorates. On the other hand, the number of S&E doctorates earned by U.S. women and members of minority groups has been increasing, and these new Ph.D. holders were more likely to enter academia than white males. By providing role models, this development will perhaps attract to the sciences and engineering some of the growing numbers of students from minority backgrounds who are expected to enroll in college over the next quarter century.

Questions arise about the changing nature of academic research and the uses of its results. The number of U.S. articles published in the world's leading S&E journals has essentially been level since the early to mid-1990s, a trend that remains unexplained. This development follows increased funding for academic R&D and coincides with reports from academic researchers that fail to show any large shift in the nature of their research. Regarding protection of intellectual property, universities moving into equity positions raise unresolved conflict-of-interest concerns for institutions and researchers. Public confidence in academia could decline should academia's research or patenting and licensing activities be perceived as violating the public interest.

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Industry, Technology, and the Global Marketplace

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Highlights

U.S. Technology in the Marketplace

- **High-technology industries are driving economic growth around the world.** The global market for high-technology goods is growing faster than that for other manufactured goods. Over the past 22 years (1980–2001), output by high-technology manufacturing industries grew at an inflation-adjusted average annual rate of 6.5 percent. Output by other manufacturing industries grew at just 2.4 percent.
- **The United States continues to be the leading producer of high-technology products and is responsible for about one-third of the world's production.** In 2001, U.S. high-technology industries accounted for 32 percent of world output.
- **The market competitiveness of individual U.S. high-technology industries varies, although each maintained strong market positions over the 22-year period examined.** Competitive pressure from a growing number of technology-producing nations has led to a reduction or flattening of U.S. market share in recent years. Between 1998 and 2001, U.S. industry lost world market share in computers and office machinery and communication equipment, maintained a rather stable market share in aerospace and pharmaceuticals, and gained market share in scientific instruments.
- **Technology products account for a larger share of U.S. exports than imports, thereby making a positive contribution to the overall U.S. trade balance.** U.S. high-technology industries contributed to the strong export performance of the nation's manufacturing industries. In 2001, exports by U.S. high-technology industries accounted for 17 percent of world high-technology exports.
- **Knowledge-intensive service industries fueled service-sector growth around the world.** Global sales in knowledge-intensive service industries exceeded $12.3 trillion in 2001, up from $8.0 trillion in 1990. The United States was the leading provider of knowledge-intensive services, responsible for between 32 and 34 percent of world revenue totals during the 22-year period examined.
- **The United States is a net exporter of technological know-how sold as intellectual property.** On average, royalties and fees received from foreign firms were three times greater than those paid out to foreigners by U.S. firms for access to their technology. In 2001, U.S. receipts from the licensing of technological know-how to foreigners totaled $4.9 billion, 24.4 percent higher than in 1999.

New High-Technology Exporters

- **Based on a model of leading indicators, Ireland and Israel appear to be headed toward prominence as technology developers and exporters in the global market.** In a group of 15 small or less-advanced countries, Ireland received the highest score in three of the four leading indicators and the second-highest score in the fourth. Israel, China, and Hungary also posted strong scores on several indicators.

International Trends in Industrial R&D

- **Internationally comparable data show a resurgence in service-sector R&D in several industrialized countries.** In 2000, service-sector industries, such as those involved in computer software development, accounted for 34 percent of all R&D performed by industry in the United States—nearly double their share in 1996. Large increases in service-sector R&D are also apparent in many European Union (EU) countries, especially Italy, the United Kingdom, and France.
- **In many industrialized countries, aerospace, motor vehicle, electronic equipment, and chemical industries conduct the largest amounts of R&D.** In the United States, industries that provide computer services and manufacture electronic equipment and industrial chemicals led the nation in R&D. In Japan, the electronic equipment industry conducted the most R&D throughout the period reviewed, followed by the chemical and motor vehicle industries. Manufacturers of industrial chemicals, motor vehicles, and electronic equipment were consistently among the top five performers of R&D in the EU.

Patented Inventions

- **In 2001, more than 166,000 patents were issued in the United States, 5 percent more than a year earlier.** U.S. resident inventors received nearly 88,000 new patents in 2001, which accounted for about 53 percent of total patents granted.
- **Patenting in the United States by foreign investors remains highly concentrated by country of origin.** From 1963 to 2001, Japan and Germany accounted for 56 percent of U.S. patents issued to foreign inventors, and the top four countries—Japan, Germany, France, and the United Kingdom—accounted for 72 percent. In 2000 and 2001, residents of Taiwan were awarded more U.S. patents than residents of France or the United Kingdom.

- **Recent U.S. patents issued to foreign inventors emphasize several commercially important technologies.** Japanese patents focus on consumer electronics, photography, photocopying and, more recently, computer technology. German inventors are developing new products and processes associated with heavy industry, such as motor vehicles, printing, advanced materials, and manufacturing technologies. Taiwanese and South Korean inventors are earning more U.S. patents in communication and computer technology.

Venture Capital and High-Technology Enterprise

- **Investor commitments to venture capital funds fell sharply, especially when compared with the large amounts of money committed during the *bubble years* (1999 and 2000).** In 1999, new commitments to venture capital funds jumped to $62.8 billion, a 111 percent gain from the previous year. By 2000, new commitments reached $105.8 billion, more than 10 times the inflow of new investor money recorded in 1995. In 2001, the inflow of new money dropped by more than 64 percent, to $37.9 billion, and totaled just $7.7 billion in 2002.
- **Internet companies continued to attract more venture capital than any other technology area in the postbubble period.** In 2001 and 2002, venture capital firms disbursed $62 billion, with more than one-fourth of this total still invested in Internet firms.
- **Not all venture capital is seed money.** During the past 10 years, money invested with entrepreneurs to prove a concept or to support early product development never accounted for more than 8 percent of total venture capital disbursements by venture capital funds and most often made up only 2 to 5 percent of the annual totals. The latest data show that the share of all venture capital classified as seed financing represents just 1 percent of total disbursements in 2001 and 2002, down from about 2 percent in 1999 and 2000.

Characteristics of Innovative U.S. Firms

- **A recent survey examining innovative activities in which information technology (IT) was a significant or critical component in developing new products or processes found that nearly half (48 percent) of responding firms developed an IT-based innovation within the past year or expected to develop one within 12 months.** Surprisingly, U.S. companies providing computer-related services were more innovative than companies manufacturing computer hardware.
- **Process innovation appears to generate more revenue for innovative firms than does product innovation.** When innovative firms were asked to identify the type of innovation (product or process) that contributed most to company revenue, the number of firms identifying process innovations outnumbered the number of firms identifying product innovations by almost 60 percent.
- **R&D continues to be important to the innovation process.** According to survey respondents, 41 percent of innovators reported that in-house R&D made a large contribution to their IT-based innovation, 31 percent said that conducting R&D was a very important part of their growth strategy, and 20 percent indicated that outsourced R&D made a large contribution toward IT-based innovation.
- **Most responding firms indicated that IT was important in conducting business.** Those firms identified as innovators placed even more emphasis on IT, with nearly 74 percent of innovators saying it was very important to their business. Firms viewed IT goods and services as very important for increasing productivity, facilitating communication, and reducing costs.

Introduction

Chapter Overview

A nation's competitiveness is often judged by its ability to both produce goods that find demand in the global marketplace and to simultaneously maintain—if not improve—the standard of living among its citizens. Science and engineering and the technological developments that emerge from S&E activities enable high-wage nations like the United States to compete with low-wage nations in today's highly competitive global marketplace. Although the U.S. economy continues to rank among the world's largest, and Americans continue to enjoy a high standard of living, many other parts of the world have advanced their technological capacity and increasingly challenge U.S. prominence in many technology areas.

This chapter focuses on industry's vital role in the nation's science and technology (S&T) enterprise and how the nation develops, uses, and commercializes the investments made in S&T by industry, academia, and government. It presents various indicators tracking the U.S. industry's national activity and its standing in the international marketplace for technology products and services, technology development, and industrial research and development performance. Using public and private data sources, U.S. industry's technology activities are compared with those of other major industrialized nations, particularly the European Union (EU) and Japan and, wherever possible, the newly or increasingly industrialized economies of Asia, Central Europe, and Latin America.[1]

Past assessments showed the United States to be a leader in many technology areas. In the chapter prepared for *Science & Engineering Indicators – 2002*, it was shown that advancements in information technologies (computers and communication products and services) drove the rising trends in new technology development and dominated technical exchanges between the United States and its trading partners. In this 2004 edition, many of the same indicators are reexamined from new perspectives influenced by international data on manufacturing and selected service industries for the advanced nations, updates to the Georgia Institute of Technology high-technology indicators model that identifies developing nations with increased technology capacities, and selected data from a recently completed survey of information technology (IT)-based innovation by the National Science Foundation (NSF).

Chapter Organization

This chapter begins with a review of industries that rely heavily on R&D, referred to herein as *high-technology industries*. No single authoritative methodology exists for identifying high-technology industries. Most calculations rely on a comparison of R&D intensities, typically determined by comparing industry R&D expenditures or the numbers of technical people employed (e.g., scientists, engineers, technicians) with the value R&D adds to the industry or the total value of the industry's shipments. In this chapter, high-technology industries are identified using the R&D intensities calculated by the Organisation for Economic Co-operation and Development (OECD).

High-technology industries are noted for their high R&D spending and performance, which produce innovations that can be applied to other economic sectors. These industries also employ and help train new scientists, engineers, and other technical personnel. Thus, the market competitiveness of a nation's technological advances, as embodied in new products and processes associated with high-technology industries, can serve as an indicator of the economic and technical effectiveness of that country's S&T enterprise.

The global competitiveness of the U.S. high-technology industry is assessed through an examination of domestic and worldwide market share trends. Data on royalties and fees generated from U.S. imports and exports of technological know-how—sold or rented as intangible (intellectual) property—are used to gauge U.S. competitiveness. Also discussed are indicators designed to identify developing and transitioning countries with the potential to become more important exporters of high-technology products over the next 15 years.

This chapter also explores several leading indicators of technology development by examining the changing emphases in industrial R&D in major industrialized countries and comparing U.S. patenting patterns with those of other nations. In addition, the disbursement of venture capital in the United States, which is money used in the formation and expansion of small high-technology companies, is examined by both the stage of development in which financing is awarded and the technology area receiving funds. The chapter concludes with a discussion of summary results from NSF's Information Technology Innovation Survey.

U.S. Technology in the Marketplace

Most countries acknowledge a symbiotic relationship between investment in S&T and success in the marketplace: S&T supports competitiveness in international trade, and commercial success in the global marketplace provides the resources needed to support new S&T. Consequently, the nation's economic health is a performance measure for the national investment in R&D and S&E.

OECD currently identifies five industries as high technology (science-based industries that manufacture products while performing above-average levels of R&D): aerospace, pharmaceuticals, computers and office machinery, communication equipment, and scientific (medical,

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[1] This chapter presents data from various public and private sources. Consequently, the countries included vary by data source.

Table 6-1
Classification of manufacturing industries based on average R&D intensity: 1991–97

Industry	ISIC rev. 3	R&D intensity Total[a]	R&D intensity United States
Total manufacturing	15–37	2.5	3.1
High-technology industries			
Aircraft and spacecraft	353	14.2	14.6
Pharmaceuticals	2423	10.8	12.4
Office, accounting, and computing machinery	30	9.3	14.7
Radio, television, and communication equipment	32	8.0	8.6
Medical, precision, and optical instruments	33	7.3	7.9
Medium-high-technology industries			
Electrical machinery and apparatus NEC	31	3.9	4.1
Motor vehicles, trailers, and semi-trailers	34	3.5	4.5
Chemicals excluding pharmaceuticals	24 excl. 2423	3.1	3.1
Railroad equipment and transport equipment NEC	352 + 359	2.4	na
Machinery and equipment NEC	29	1.9	1.8
Medium-low-technology industries			
Coke, refined petroleum products, and nuclear fuel	23	1.0	1.3
Rubber and plastic products	25	0.9	1.0
Other nonmetallic mineral products	26	0.9	0.8
Building and repairing of ships and boats	351	0.9	na[b]
Basic metals	27	0.8	0.4
Fabricated metal products, except machinery and equipment	28	0.6	0.7
Low-technology industries			
Manufacturing NEC and recycling	36–37	0.4	0.6
Wood, pulp, paper, paper products, printing, and publishing	20–22	0.3	0.5
Food products, beverages, and tobacco	15–16	0.3	0.3
Textiles, textile products, leather, and footwear	17–19	0.3	0.2

ISIC International Standard Industrial Classification
na not applicable
NEC not elsewhere classified

[a] Aggregate R&D intensities calculated after converting R&D expenditures and production using 1995 gross domestic product purchasing power parities.
[b] R&D expenditures in "shipbuilding" (351) are included in "other transport" (352 + 359).

NOTE: R&D intensity is direct R&D expenditures as a percent of production (gross output).

SOURCES: Organisation for Economic Co-operation and Development, ANBERD and STAN databases, May 2001.

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precision, and optical) instruments.[2] These five industries, identified as the most R&D intensive by OECD, are also the most R&D intensive for the United States (table 6-1).

This section reviews the U.S. position in the global marketplace from several vantage points: its position in the high-technology product market, the competiveness of individual industries, and trends in U.S. exports and imports of technological know-how.

Importance of High-Technology Industries

High-technology industries are important to nations for several reasons. High-technology firms innovate, and firms that innovate tend to gain market share, create new product markets, and use resources more productively (NRC, Hamburg Institute for Economic Research, and Kiel Institute for World Economics 1996; and Tassey 2000). High-technology firms develop high value-added products and are successful in foreign markets, which results in greater compensation for their employees. Industrial R&D performed by high-technology industries benefits other commercial sectors by generating new products and processes that increase productivity, expand business, and create high-wage jobs.

According to the Global Insight World Industry Service database, which provides production data for 70 countries that account for more than 97 percent of global economic activity, the global market for high-technology goods is growing at a faster rate than that for other manufactured goods, and high-technology industries are driving economic

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[2] In designating these high-technology industries, OECD took into account both direct and indirect R&D intensities for 13 countries: the United States, Japan, Germany, France, the United Kingdom, Canada, Italy, Spain, Sweden, Denmark, Finland, Norway, and Ireland. Direct intensities were calculated as the ratio of R&D expenditure to output (production) in 22 industrial sectors. Each sector was weighted according to its share of the total output among the 13 countries, using purchasing power parities (PPPs) as exchange rates. Indirect intensities were calculated by using the technical coefficients of industries on the basis of input-output matrices. OECD then assumed that, for a given type of input and for all groups of products, the proportions of R&D expenditure embodied in value added remained constant. The input-output coefficients were then multiplied by the direct R&D intensities. For further details concerning the methodology used, see OECD (2001).

growth around the world. During the 22-year period examined (1980–2001), high-technology production grew at an inflation-adjusted average annual rate of nearly 6.5 percent compared with 2.4 percent for other manufactured goods. Global economic activity was especially strong at the end of the period (1996–2001), when high-technology industry output grew at 8.9 percent per year, more than double the rate of growth for all other manufacturing industries (figure 6-1 and appendix table 6-1). Output by the five high-technology industries represented 7.7 percent of global production of all manufactured goods in 1980; by 2001, it doubled to 15.8 percent.

During the 1980s, the United States and other high-wage countries committed to increasing the resources used in the manufacture of higher value-added, technology-intensive goods, often referred to as *high-technology manufactures.* (See sidebar, "U.S. High-Technology Industries Add More Value During Production Than Other U.S. Manufacturing Industries.") During this period, the United States led the major industrialized countries in concentration on high-technology manufactures. In 1980, high-technology manufactures accounted for about 10 percent of total U.S. production. By 1984, it had increased to 13 percent and in 1989 was nearly 14 percent. By contrast, high-technology manufactures represented about 12 percent of total Japanese production in 1989, up from 7.3 percent in 1980. European nations also saw high-technology manufactures account for a growing share of their total production, although to a lesser degree. The one exception was the United Kingdom, where high-technology manufactures rose from 9 percent of total manufacturing output in 1980 to 12.5 percent in 1989.

The major industrialized countries continued to emphasize high-technology manufactures throughout the 1990s (figure 6-2 and appendix table 6-1). In 1999, high-technology manufactures were estimated to be 20.9 percent of manufacturing output in the United States, 17.0 percent in the United Kingdom, 16.2 percent in France, 15.8 percent in Japan, and 9.3 percent in Germany. The latest data through 2001 show output in high-technology industries continued to grow faster than output in other manufacturing industries in the United States, Germany, and France, while slowing somewhat in Japan and the United Kingdom.

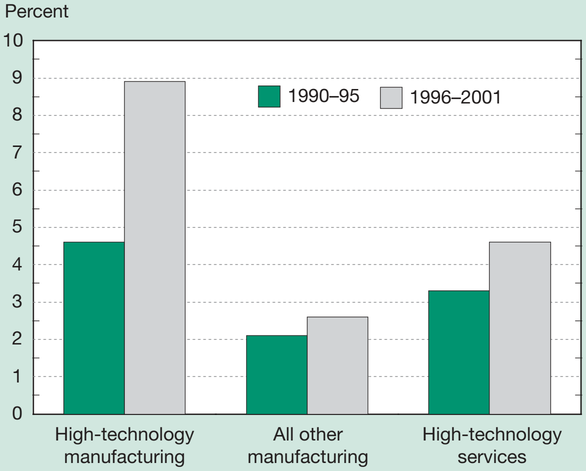
Taiwan and South Korea typify how important R&D-intensive industries are to newly industrialized economies. In 1980, high-technology manufactures accounted for 8.2 percent of Taiwan's total manufacturing output; this proportion jumped to 12.4 percent in 1989 and reached 29.2 percent in 2001. The transformation of South Korea's manufacturing base is even more striking. High-technology manufacturing in South Korea accounted for 6.1 percent of total output in 1980, 10.0 percent in 1989, and 31.0 percent in 2001.

Share of World Markets

From 1980 through 2001, the United States has consistently been the world's leading producer of high-technology products. U.S. high-technology industries' shares of world output fluctuated between 29 and 33 percent, rising slightly in the late 1990s before falling in 2000 and 2001. In 2001, U.S. high-technology industries accounted for about 32 percent of world output.

The EU lost high-technology market share gradually during the 1980s and 1990s. High-technology industries in the EU's 15 nations accounted for 22.8 percent of world output in 2001, which was a small increase from 2000 but generally reflects a persistent decline in the European share since the early 1980s. Among the four large EU countries, the United Kingdom, Germany, and Italy each recorded smaller shares,

Figure 6-1
Global industry sales, average annual growth rate, by sector: 1990–2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

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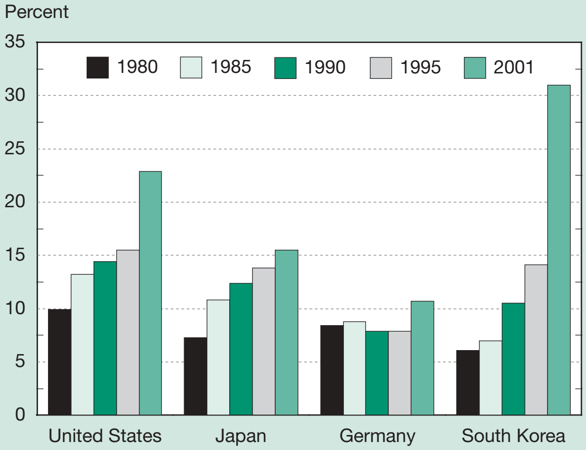
Figure 6-2
High-technology industry share of total manufacturing output in selected countries: 1980–2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

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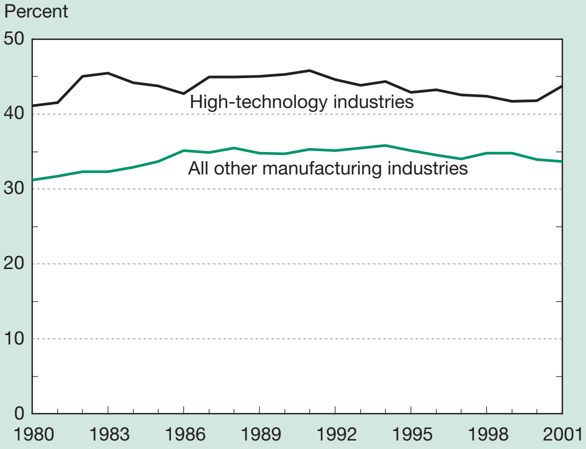
U.S. High-Technology Industries Add More Value During Production Than Other U.S. Manufacturing Industries

Historically, manufacturing has incorporated processes and production steps that occur in different locations, at different times, and in different countries. In today's highly competitive global marketplace, manufacturers in countries with high standards of living and labor costs have increasingly moved manufacturing operations to locations with lower labor costs. High-technology industries and their factories are coveted by local, state, and national governments because these industries consistently show greater levels of "in-house" production (value added) in the final product than other manufacturing industries. In the United States, high-technology industries reported about 30 percent more value added than other manufacturing industries (figure 6-3). High-technology industries also generally pay their workers higher wages than they would receive in other manufacturing industries.

Gross value added in this summary equals gross output minus the cost of intermediate inputs and supplies. That is, value added is the amount of revenue generated by product sales that is available to pay wages, interest on loans, rents, and profits to the business owners after production costs are paid.

Value added can be an important indicator of economic and technological progress in developing countries. When foreign investments and foreign corporations control major portions of a developing country's manufacturing base, data on domestic value added and its contribution to final output can indicate the extent to which those corporations are transferring technological and manufacturing know-how to the host country. For example, Singapore and Malaysia have actively pursued policies that encourage foreign investment with the expectation that, over time, domestic content would grow larger. As shown in figure 6-4, the amount of value added by manufacturing industries in those two countries, as measured by value added as a percentage of the value of final output, has fluctuated over time but generally increased in both high-technology and other manufacturing industries.

Figure 6-3
Value added by U.S. industries as percentage of gross output: 1980–2001



NOTE: Conceptually, value added is the value of final production less the value of purchased inputs used in the production process.

SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

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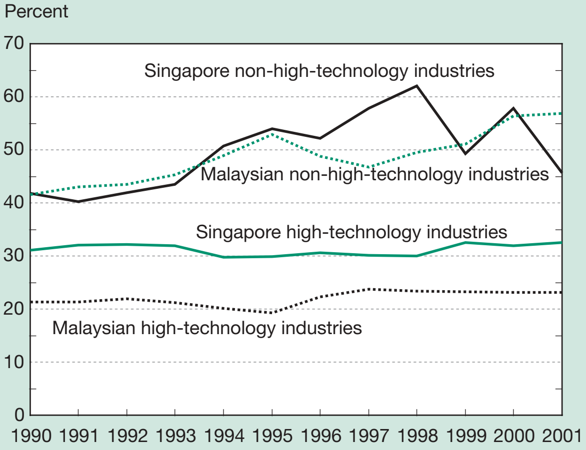
Figure 6-4
Value added in Singapore and Malaysian industries as percentage of gross output: 1990–2001



NOTE: Conceptually, value added is the value of final production less the value of purchased inputs used in the production process.

SOURCE: Global Insight Inc. World Industry Service database, 2003. See appendix table 6-1.

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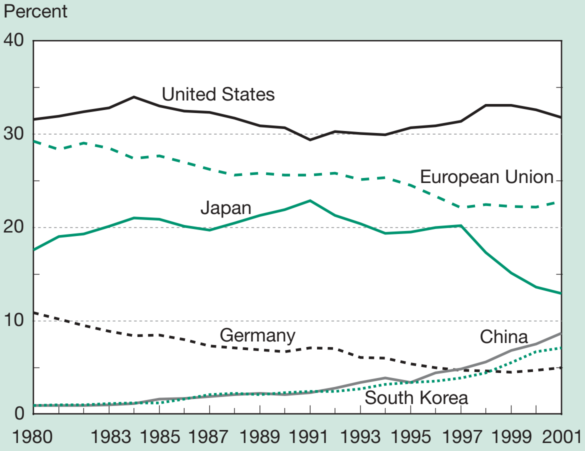
although Germany reversed its decline somewhat from 1999 to 2001. Only France gained market share over the 22-year period examined, and in 2001, it led EU countries with a 5.5 percent share. Germany accounted for 5.0 percent and the United Kingdom for 4.1 percent. Italy's shares were the lowest among the four large European economies, ranging from a high of about 3.5 percent during the mid-1980s to a low of about 1.8 percent in 2000 and 2001.

Asia's market share grew over the past 2 decades, led first by Japan in the 1980s and then by South Korea and China in the 1990s. In 1989, Japan accounted for 21.3 percent of the world's production of high-technology products, moving up 4 percentage points from its 1980 share. Japan continued to gain market share through 1991. Since then, however, its market position has deteriorated, with the steepest declines evident after 1997. In 2001, Japan's share fell to 12.9 percent, its lowest level in the 1980–2001 period examined (figure 6-5).

As Japan's dominance waned, developing Asian nations made dramatic gains. South Korea's market share more

Figure 6-5
Country share of global high-technology market in selected countries: 1980–2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

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than doubled during the 1980s, moving from 0.9 percent in 1980 to 2.1 percent in 1989, and then increased each year throughout the 1990s. By 2000, it had jumped to 6.5 percent, and by 2001 it measured 7.1 percent, its highest level in the 22 years examined. The growth in China's high-technology output surpassed that of South Korea. In 1980, China's high-technology industry produced just 0.9 percent of the world's output. That figure rose to 2.2 percent in 1989, 5.5 percent in 1999, and 8.7 percent in 2001.

Global Competitiveness of Individual Industries

In each of the five industries that make up the high-technology group, the United States maintained strong, if not leading, market positions between 1980 and 2001. The United States is a large and mostly open market, characteristics that benefit U.S. high-technology producers in two important ways. First, supplying a market with many consumers results in scale effects for U.S. producers because there are potentially large rewards for new ideas and innovations (Romer 1996). Second, the openness of the U.S. market to competing, foreign-made technologies pressures U.S. producers to be more innovative to maintain domestic market share.

Two U.S. high-technology industries, computers and office machinery and communication equipment, reversed downward trends resulting from competitive pressures from a growing cadre of high-technology-producing nations during the 1980s. These industries gained market share in the mid- to late 1990s in part due to increased capital investment by U.S. businesses. (See sidebar, "U.S. Industry Continues to Invest in IT.")

Since 1997, the United States has been the leading supplier of office and computer machinery in the global market, overtaking longtime leader Japan. The EU, led by Germany, was the dominant producer for most of the 1980s before relinquishing the lead to Japan in 1988. Among developing countries, China and South Korea showed rapid and consistent growth in global market share, especially in the late 1990s.

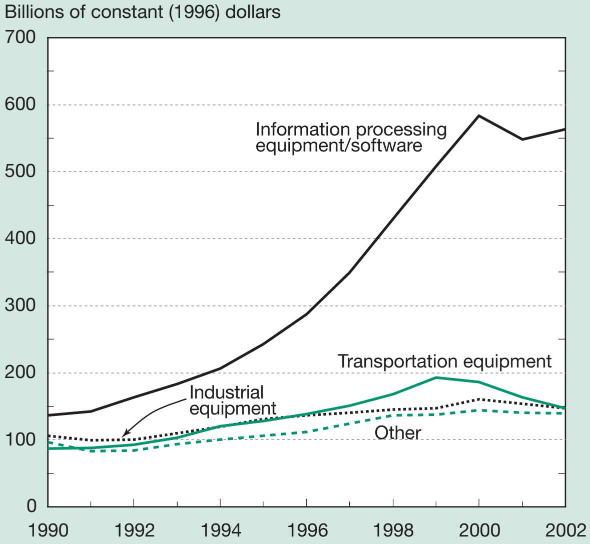
U.S. Industry Continues to Invest in IT

Information technology (IT) was a major contributor to innovation and productivity gains during the 1990s. In addition to the technical changes within IT itself, companies used IT to transform the way their products performed and the way their services were delivered. IT was also used to improve the flow of information within and among organizations, which led to productivity gains and production efficiencies.

Throughout the period 1990–2002, U.S. industry purchases of IT equipment and software exceeded industry spending on all other types of capital equipment (figure 6-6). At its peak in 2000, U.S. industry spending on IT was more than three times the amount that all industries spent on industrial equipment, and it exceeded combined industry spending on industrial, transportation, and all other equipment.

Despite the economic downturn that began in spring of 2000, U.S. companies continued to invest heavily in IT. Industry spending on IT equipment and software accounted for 44 percent of all nonresidential investment (including structures and equipment) by industries in 2000, and about 48 percent in 2002.

Figure 6-6
Industry spending on capital equipment: 1990–2002



SOURCE: U.S. Bureau of Economic Analysis, http://www.bea.doc.gov/bea/dn/nipaweb/TableViewFixed.asp?SelectedTable=68&FirstYear=2002&LastYear=2003&Freq=Qtr

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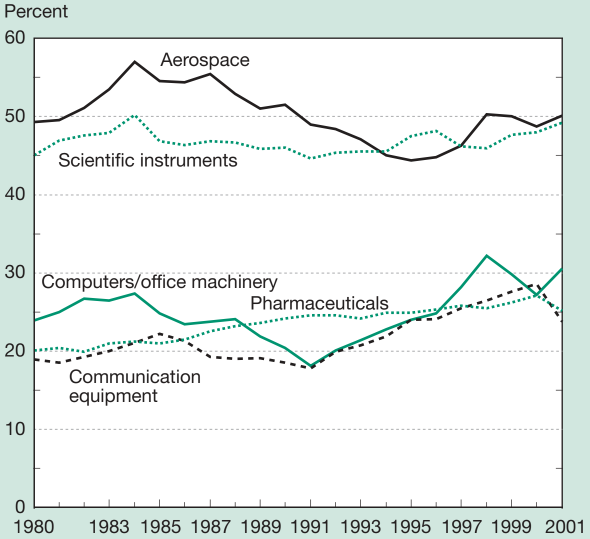
Figure 6-7
U.S. global market share, by high-technology industry: 1980–2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

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From 1980 through 1997, Japan was the world's leading supplier of communication equipment, exceeding output in the United States and the EU. In 1998, U.S. manufacturers once again became the leading producer of communication equipment in the world and have since retained that position. In 2001, the latest year for which data are available, the United States accounted for approximately 24 percent of world production of communication equipment, down from 29 percent in 2000 (figure 6-7 and appendix table 6-1).

Aerospace, the U.S. high-technology industry with the largest world market share, was the only industry to lose market share during the 1990s. During the early 1980s, the U.S. aerospace industry consistently gained market share, peaking at 57 percent in 1984. Since then, the U.S. share of this market has generally declined, falling to 51 percent in 1989 and to about 44 percent in 1995. The industry recovered somewhat during the following 3 years, then leveled off at about a 50 percent share in 2001. European aerospace industries made some gains during this time, particularly in France. After fluctuating between 7 and 10 percent during the 1980s, the French aerospace industry slowly gained market share for much of the 1990s. In 2000, France supplied 12.8 percent of world aircraft shipments; in 2001, that figure reached 13.5 percent. The EU as a whole accounted for 30.2 percent of world aircraft shipments in 2001. China's aerospace industry also grew relatively sharply. In 1980, China's aerospace industry output accounted for less than 1 percent of world output; by 1989, its market share rose to 1.5 percent. A succession of year-to-year gains from 1992 through 1997 then lifted its market share to 5.8 percent, and in 2000 and 2001 it stood at 6.5 percent. Brazil exhibited a very different trend. Brazil accounted for 14.9 percent of world aerospace production in 1980, 10.2 percent in 1989, and 2.8 percent in 2001.

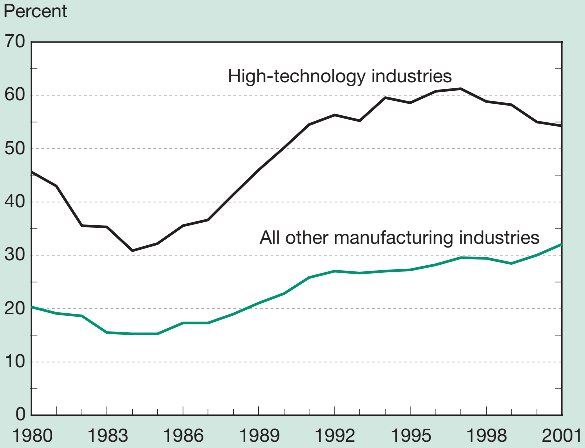
The EU was the leading producer of drugs and medicines in the world market for the entire 22-year period examined and accounted for 30–34 percent of global shipments. France is the leading producer among the four largest EU member nations. The U.S. market share grew irregularly, from 20 percent in 1980 to 24 percent in 1990, and to 25 percent in 2001. Different national laws governing the distribution of foreign pharmaceuticals make this industry unique compared with other high-technology industries. For this industry, domestic population dynamics may play a more important role than global market forces and affect the demand for a country's pharmaceutical products.

The 2001 addition of the scientific instruments industry (medical, precision, and optical instruments) to the group of high-technology industries reflects the industry's high level of R&D in advanced nations (table 6-1). From 1980 through 2001, the United States was the leading producer of scientific instruments. In 2001, the United States accounted for 49.3 percent of global industry shipments, up from 46.0 percent in 1990 and 45.1 percent in 1980. The EU, led by Germany and France, ranked second, accounting for 28–31 percent of global shipments.

Exports by High-Technology Industries

Although U.S. producers benefit from having the world's largest home market as measured by gross domestic product (GDP), mounting trade deficits highlight the need to serve foreign markets as well. Traditionally, U.S. high-technology industries have been more successful exporting their products than other U.S. industries, and therefore can play a key role in returning the United States to a more balanced trade position (figure 6-8).

Figure 6-8
U.S. exports as percentage of gross output: 1980–2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

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Foreign Markets

Despite its domestic focus, the United States was an important supplier of manufactured products to foreign markets throughout the 1980–2001 period. Throughout the 1990s and continuing through 2001, U.S. industry supplied 13–14 percent of the world's general manufacturing exports. It ranked second only to the EU in its share of world exports. If intra-EU shipments were excluded, the United States would likely rank above the EU.

Exports by U.S. high-technology industries grew rapidly during the mid-1990s and contributed to the nation's strong export performance (figure 6-9). During the 1990s, U.S. high-technology industries accounted for between 19 and 23 percent of world high-technology exports, which at times were nearly twice the level achieved by all U.S. manufacturing industries. In 2001, the latest year for which data are available, exports by U.S. high-technology industries accounted for about 17 percent of world high-technology exports; Japan accounted for about 10 percent, and Germany nearly 8 percent.

The gradual drop in the U.S. share during 1990–2001 was in part due to competition from emerging high-technology industries in newly industrialized economies, especially in Asia. High-technology industries in South Korea and Taiwan each accounted for about 2.5 percent of world high-technology exports in 1990, and data for 2001 show that each country's share nearly doubled. Singapore's share, which was 3.5 percent in 1990 and 5.7 percent in 2001, was also significant.

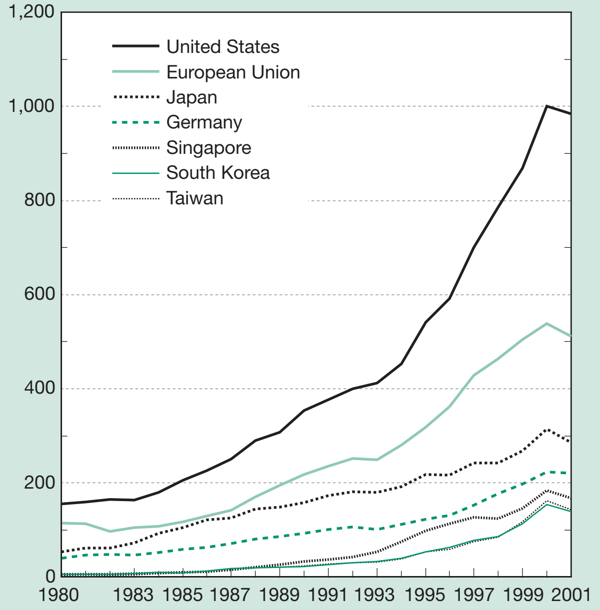
Industry Comparisons

Over the past 2 decades, U.S. high-technology industries were leading exporters in each of the five industries that comprise the high-technology group. The United States was the export leader in all five industries in 2001, although its shares in several categories declined.

U.S. aerospace technology, computers and office machinery, and communication equipment industries all recorded successively smaller shares of world exports in 2001 than in earlier years. U.S. exports of aerospace technologies accounted for 54 percent of world aerospace exports in 1980, 46 percent in 1990, and 38 percent in 2001. U.S. exports of computers and office machinery represented 31 percent of world exports in 1980, 22 percent in 1990, and 16 percent in 2001. The U.S. manufacturers of communication equipment's share has fluctuated in a much narrower range, 13–17 percent, reaching highs in the early 1980s and the mid-1990s before falling to lows in 2000 and 2001. U.S. exports of scientific instruments declined throughout most of the 1980s, remained stable through the mid-1990s, and have slowly climbed since then. In 2001, U.S. exports of scientific instruments accounted for approximately 22 percent of world exports (figure 6-10 and appendix table 6-1). The only U.S. industry with a higher share of world exports in 2001 than in 1980 was the pharmaceutical industry, which rose from 12 to 15 percent.

Figure 6-9
High-technology exports in selected countries: 1980–2001

Billions of 1997 U.S. dollars



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

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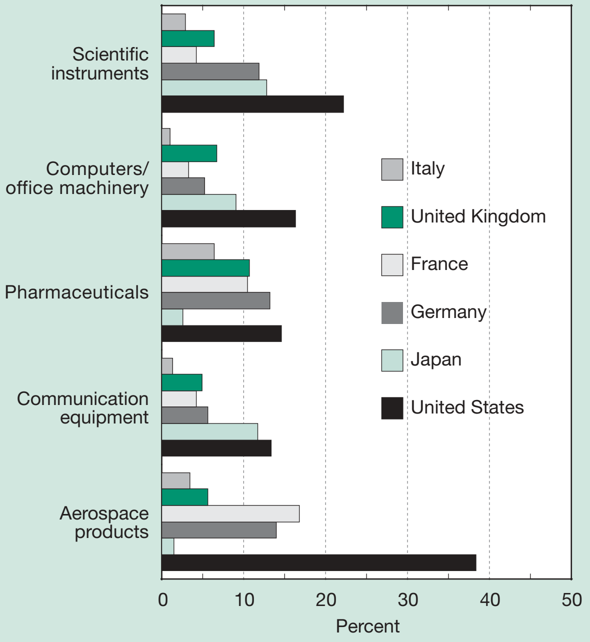
Figure 6-10
World exports in high-technology industries in selected countries: 2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

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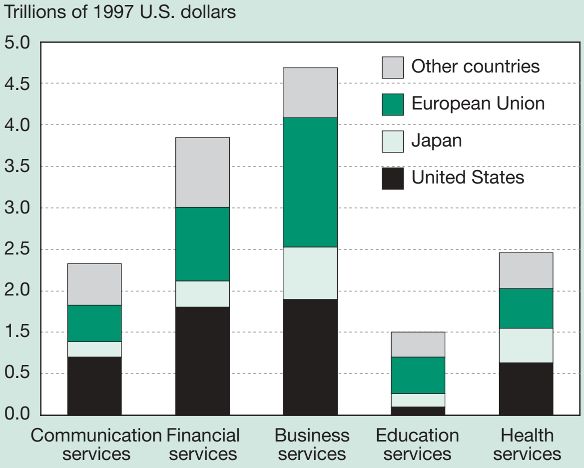
Figure 6-11

Global revenues generated by five knowledge-intensive service industries in selected countries: 2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-2.

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Global Business in Knowledge-Intensive Service Industries

For several decades, revenues generated by U.S. service-sector industries grew faster than those generated by the nation's manufacturing industries. Data collected by the U.S. Department of Commerce show that the service sector's share of U.S. GDP grew from 49 percent in 1959 to 64 percent in 1997 (NSB 2000, appendix table 9-4). This growth has been fueled largely by *knowledge-intensive* industries—those that incorporate science, engineering, and technology in either their services or the delivery of their services.[3] Five of these knowledge-intensive industries are the communication, financial, business (including computer software development), educational, and health services. In the United States, these industries grew faster than the high-technology manufacturing sector discussed earlier. This section presents data tracking the overall revenues earned by these industries in 70 countries[4] (figure 6-11 and appendix table 6-2).

Combined global sales in these service-sector industries exceeded $12.3 trillion in 2001, up from $5.4 trillion in 1980 and $8.0 trillion in 1990. The United States was the leading provider of high-technology services, responsible for about one-third of total world service revenues during the 22-year period examined.

Business services, which include computer and data processing and research and engineering services, was the largest of the five service industries and accounted for 34 percent of global revenues in 2001. It was most prominent in the EU, which claimed 37 percent of business services world revenue in 2001. The United States ranked second at nearly 34 percent, followed by Japan at 15 percent. Data on individual business services by country are not available.

Financial services was the second largest service sector and accounted for nearly 27 percent of global revenues in 2001. Forty percent of industry revenues in 2001 went to the U.S. financial services industry, the world's largest. The EU was second with approximately 26 percent, followed by Japan at nearly 10 percent.

Communication services, which include telecommunication and broadcast services, was the fourth-largest service industry examined, accounting for almost 15 percent of world service industry revenues in 2001. In what many consider the most technology-driven of the service industries, the United States held the dominant position. In 2001, U.S. firms generated revenues equal to 38 percent of world revenues. The EU accounted for 24 percent, and Japan accounted for nearly 11 percent.

Because many nations' governments serve as the primary provider of the remaining two knowledge-intensive service industries, health services and educational services, and because the size of each country's population affects the delivery of these services, global comparisons based on market-generated revenues are less meaningful than they are for other service industries. The United States, with arguably the least government involvement, has the largest health services industry in the world. The EU is second, followed by Japan. If most of these services are delivered primarily to domestic customers, then, on a per capita basis, Japanese residents clearly consumed the most health services of any advanced nation. Educational services, the smallest of the five knowledge-intensive service industries in terms of revenue generated, includes governmental and private education institutions of all types that offer primary, secondary, and university education, as well as technical, vocational, and commercial schools. By comparison, fees (tuition) and income from other education service-related operations accounted for about one-fourth of the revenues generated by the business services industry worldwide. Europe generated the most revenues in this service industry, with Japan second and the United States third. Again, on a per capita basis, Japanese residents consumed more educational services than residents in any other advanced nation.

U.S. Royalties and Fees Generated From Intellectual Property

The United States has traditionally maintained a large trade surplus in intellectual property. Firms trade intellectual property when they license or franchise proprietary technologies, trademarks, and entertainment products to entities in other countries. These transactions generate revenues in the form of royalties and licensing fees.

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[3] See OECD (2001) for discussion of classifying economic activities according to degree of "knowledge-intensity."

[4] Unlike the manufacturing industries, national data that track activity in many rapidly growing service sectors are limited in the level of industry disaggregation and the types of data collected.

U.S. Royalties and Fees From All Transactions

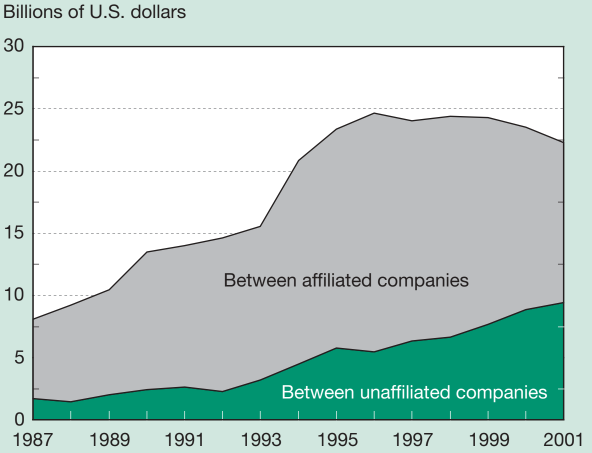
In 2001, U.S. receipts from trade in intellectual property declined for the first time since 1987. After an increase throughout the late 1980s and 1990s, total receipts peaked in 2000 at nearly $40 billion, then dropped somewhat in 2001. U.S. receipts for transactions involving intellectual property generally were four to five times larger than U.S. payments to foreign firms. This gap narrowed in the late 1990s as U.S. payments increased faster than U.S. receipts. This trend continued for 3 years and, by 2000, the ratio of receipts to payments dropped to about 2.5:1.

In 2001, U.S. trade in intellectual property produced a surplus of $22.3 billion, down 5 percent from the $23.5 billion surplus recorded a year earlier and extending a downward trend that began in 1999 (figure 6-12 and appendix table 6-3). About 75 percent of transactions involved exchanges of intellectual property between U.S. firms and their foreign affiliates.[5] Exchanges of intellectual property among affiliates grew at about the same pace as those among unaffiliated firms. These trends suggest both a growing internationalization of U.S. business and a growing reliance on intellectual property developed overseas.

U.S. Royalties and Fees From Trade in Technical Knowledge

Data on royalties and fees generated by trade in intellectual property can be further disaggregated to reveal U.S. trade in technical know-how. By tracking transactions between unaffiliated firms in which prices are set through market-based negotiation, these data may better reflect the value of technical know-how at a given time than data on exchanges among affiliated firms. When receipts (sales of technical know-how) consistently exceed payments (purchases), these data may indicate a comparative advantage in the creation of industrial technology. Tracking the record of receipts and payments also provides an indicator of trends in the production and diffusion of technical knowledge.

Figure 6-12
U.S. trade balance of royalties and fees: 1987–2001



SOURCE: U.S. Bureau of Economic Analysis, *Survey of Current Business,* 2002. See appendix table 6-3.

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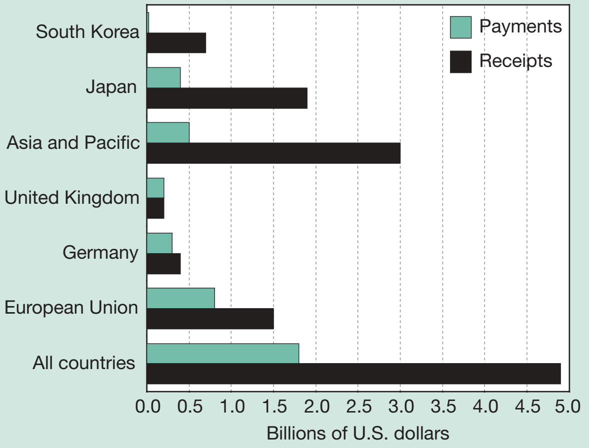
The United States is a net exporter of technology sold as intellectual property. The gap between imports and exports narrowed during the late 1990s, but the most recent data show a surge in receipts in 2000 that outpaced the growth in payments. During the early 1990s, royalties and fees received from foreign firms were an average of three times greater than the amount U.S. firms paid foreigners for access to their technology. U.S. receipts grew to $3.9 billion in 1999, and in 2001 totaled $4.9 billion, an increase of approximately 24 percent (figure 6-13 and appendix table 6-4). The slower growth in the most recent year may be due in part to past transfers of intellectual property to foreign affiliates of U.S. firms who in turn take the place of the U.S. parent company when dealing directly with foreign customers. Such transfers are advantageous for U.S. firms when the affiliates are located in countries with lower tax rates or when the transfers facilitate local product adaptation (Borga and Mann 2002). In transactions between unaffiliated firms, U.S. receipts for technology sold as intellectual property exceeded payments by more than $3 billion in 2000 and 2001.

The U.S. trade surplus in intellectual property is driven largely by trade with Asia. In 1995, U.S. receipts (exports) from technology licensing transactions were nearly seven times the amount of U.S. payments (imports) to Asia. That ratio closed to slightly more than 4:1 by 1997, but has since widened. The most recent data show U.S. receipts from

Figure 6-13
U.S. royalties and fees generated from exchange of industrial processes between unaffiliated companies in selected countries: 2001



SOURCE: U.S. Bureau of Economic Analysis, *Survey of Current Business,* 2002. See appendix table 6-4.

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[5] An *affiliate* refers to a business enterprise located in one country that is directly or indirectly owned or controlled by an entity in another country. The controlling interest for an incorporated business is 10 percent or more of its voting stock; for an unincorporated business, it is an interest equal to 10 percent of voting stock.

technology licensing transactions at more than six times the amount of U.S. payments to Asia. Japan and South Korea were the biggest customers for U.S. technology sold as intellectual property; together, these countries accounted for 54 percent of total receipts in 2001.

Japan was the single largest consumer, although its purchases declined significantly during the 1990s. At its peak in 1993, Japan's share of U.S. receipts was approximately 51 percent. Japan's purchases began to increase again in 2000 and 2001, raising its share to 35 and 39 percent, respectively. Another Asian country, South Korea, was the second largest consumer, accounting for nearly 15 percent of U.S. receipts in 2001. South Korea has been a major consumer of U.S. technological know-how since 1988, when it accounted for 5.5 percent of U.S. receipts. South Korea's share rose to nearly 11 percent in 1990 and reached its highest level, 19 percent, in 2000.

Unlike its trade with Asia, U.S. trade in intellectual property with Europe fluctuated between surplus and deficit until 1994, when a sharp decline in U.S. purchases of European technical know-how led to a considerably larger surplus for the United States than in previous years. Another large surplus in 1995 resulted from an increase in receipts from the larger European countries. Receipts from EU countries have risen steadily since 1997, reaching $1.4 billion in 2001, or about 28 percent of all U.S. receipts for technology sold as intellectual property. Some of this increase can be attributed to increased licensing activity by firms in Germany, the third-largest consumer of U.S. technological know-how. In 2001, German firms spent $368 million, approximately double their expenditures in 1997. The latest data also show that U.S. receipts from exchanges with France and Switzerland rose sharply during the late 1990s and again in 2000 and 2001, leading to considerably larger U.S. surpluses from trade with Europe.

Foreign sources for U.S. firms' purchases of technical know-how varied over the years. The EU has been the biggest supplier for U.S. firms, accounting for 40–55 percent of foreign-supplied purchases of technological know-how sold as intellectual property. Germany, the United Kingdom, and Switzerland are the principal European suppliers.[6]

Asia has also been an important supplier of technological know-how, although its share of U.S. purchases has dropped considerably since 1999. In 2001, Asian countries accounted for 26 percent of U.S. purchases, down from 39 percent in 1999. Japan is the source for nearly all of the U.S. purchases from Asia, with small amounts coming from South Korea and Taiwan. Since 1992, Japan has been the single largest foreign supplier of technical know-how to U.S. firms: about one-fourth of 2001 U.S. payments were made to Japanese firms.

New High-Technology Exporters

Several nations made tremendous technological advances over the past decade and are positioned to become more prominent in technology development because of their large, ongoing investments in S&E education and R&D.[7] However, their success may depend on other factors as well, including political stability, access to capital, and an infrastructure that can support technological and economic advancement.

This section assesses a group of selected countries and their potential to become more important exporters of high-technology products during the next 15 years, based on the following leading indicators:[8]

- **National orientation**—evidence that a nation is taking action to become technologically competitive, as indicated by explicit or implicit national strategies involving cooperation between the public and private sectors.
- **Socioeconomic infrastructure**—the social and economic institutions that support and maintain the physical, human, organizational, and economic resources essential to a modern, technology-based industrial nation. Indicators include the existence of dynamic capital markets, upward trends in capital formation, rising levels of foreign investment, and national investments in education.
- **Technological infrastructure**—the social and economic institutions that contribute directly to a nation's ability to develop, produce, and market new technology. Indicators include the existence of a system for the protection of intellectual property rights, the extent to which R&D activities relate to industrial application, competency in high-technology manufacturing, and the capability to produce qualified scientists and engineers.
- **Productive capacity**—the physical and human resources devoted to manufacturing products and the efficiency with which those resources are used. Indicators include the current level of high-technology production, the quality and productivity of the labor force, the presence of skilled labor, and the existence of innovative management practices.

This section is an analysis of 15 economies: 6 in Asia (China, India, Indonesia, Malaysia, the Philippines, and Thailand), 3 in Central Europe (Czech Republic, Hungary, and Poland), 4 in Latin America (Argentina, Brazil, Mexico, and Venezuela), and 2 others (Ireland and Israel) that showed increased technological activity.[9]

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[6] France has also been an important source of technological know-how over the years. In 1996, France was the leading European supplier to U.S. firms. Since then, data for France have been intermittently suppressed to avoid disclosing individual company operations. Data were last published for France in 2000 and showed a sharp drop in U.S. purchases of French technological know-how compared with 1996 data.

[7] See chapter 2 for a discussion of international higher education trends and chapter 4 for a discussion of trends in U.S. R&D.

[8] See Porter and Roessner (1991) for details on survey and indicator construction; see Roessner, Porter, and Xu (1992) for information on the validity and reliability testing the indicators have undergone.

[9] See notes to appendix table 6-5 for a complete description of data used in each of the four indicators.

National Orientation

The national orientation indicator identifies nations in which businesses, government, and culture encourage high-technology development. It was constructed using information from a survey of international experts and previously published data. The survey asked the experts to rate national strategies that promote high-technology development, social influences that favor technological change, and entrepreneurial spirit. Published data were used to rate each nation's risk factor for foreign investment during the next 5 years (PRS Group 2002).

Ireland and Israel posted by far the highest overall scores on this indicator (figure 6-14 and appendix table 6-5). Although Ireland scored slightly lower than Israel on each of the expert-opinion components, its rating as a much safer place for foreign investment than Israel elevated its composite score.

The national orientations of both Ireland and Israel were scored consistently and significantly higher than those of other countries examined and were well within the range of scores accorded the more advanced economies of Taiwan and Singapore. Malaysia, Hungary, Poland, the Czech Republic, China, and India also scored well, with strong scores in each indicator component.

Indonesia, Thailand, and two Latin American countries, Argentina, and Venezuela, received the lowest composite scores of the economies examined. Indonesia and Thailand were rated low on all variables but were hurt most because they were considered riskier or less attractive sites for foreign investment. Argentina and Venezuela also received consistently low scores on each variable and were hurt most by the expert perception that these three countries were not entrepreneurial.

Socioeconomic Infrastructure

The socioeconomic infrastructure indicator assesses the underlying physical, financial, and human resources needed to support modern, technology-based nations. It was built from published data on percentages of the population in secondary school and in higher education and survey data evaluating the mobility of capital and the extent to which foreign businesses are encouraged to invest and do business in that country[10] (figure 6-14).

Ireland and Israel again received the highest scores among the emerging and transitioning economies examined. In addition to their strong records in general and higher education, Ireland's and Israel's scores reflect high ratings for the mobility of capital and encouragement of foreign businesses to invest there. Their scores were similar to those of Taiwan and South Korea.

Among remaining nations, Malaysia and the three Central European countries all posted similar high scores. The socioeconomic infrastructure score for Malaysia was bolstered by the experts' high opinion of the mobility of capital in the country, whereas the Central European countries received high scores for their strong showing in the published education data.

Indonesia received the lowest composite score of the 15 nations examined. It was held back by low marks on two of the three variables: educational attainment (particularly university enrollments) and the variable rating of its mobility of capital.

Technological Infrastructure

Five variables were used to develop the technological infrastructure indicator, which evaluates the institutions and resources that help nations develop, produce, and market new technology. This indicator was constructed using published data on the number of scientists in R&D; published data on national purchases of electronic data processing (EDP) equipment; and survey data that asked experts to rate each nation's ability to locally train its citizens in academic S&E, make effective use of technical knowledge, and link R&D to industry.

China and Israel received the highest scores of the group of newly industrialized or transitioning economies examined (figure 6-14). China's score was influenced greatly by the two components that reflect the size of its population: its large purchases of EDP equipment and its large number of scientists and engineers engaged in R&D. Israel's high score on this indicator was based on its large number of trained scientists and engineers, the size of its research enterprise, and its contribution to scientific knowledge. Indonesia and Venezuela again recorded the lowest scores among the 15 countries examined.

Productive Capacity

The productive capacity indicator evaluates the strength of a nation's manufacturing infrastructure and uses that evaluation as a baseline for assessing the country's capacity for future growth in high-technology activities. The indicator considers expert opinion on the availability of skilled labor, the number of indigenous high-technology companies, and the level of management ability, combined with published data on current electronics production in each country.

Ireland scored highest in productive capacity among the 15 developing and transitioning nations examined, receiving high marks for each indicator component (figure 6-14). Its score was boosted by its prominence in the computer hardware manufacturing industry. China, Israel, and India followed closely, with each posting strong scores on all indicator components.

Several developing Asian economies, particularly China and Malaysia, had higher electronics production than Ireland in 1999, the reference year for the published data. However, they scored lower on indicator components rating their labor pools and management personnel. Mexico's production of

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[10] The Harbison-Myers Skills Index, which measures the percentage of the population attaining secondary and higher education, was used for these education-based assessments. See appendix table 6-5 for complete source reference.

Figure 6-14
Leading indicators of technological competitiveness in selected countries: 2002

NOTE: Raw data were converted into scale of 0–100 for each indicator component.

SOURCE: Georgia Technology Research Co., *High Tech Statistics, Preliminary Report,* 2003. See appendix table 6-5.

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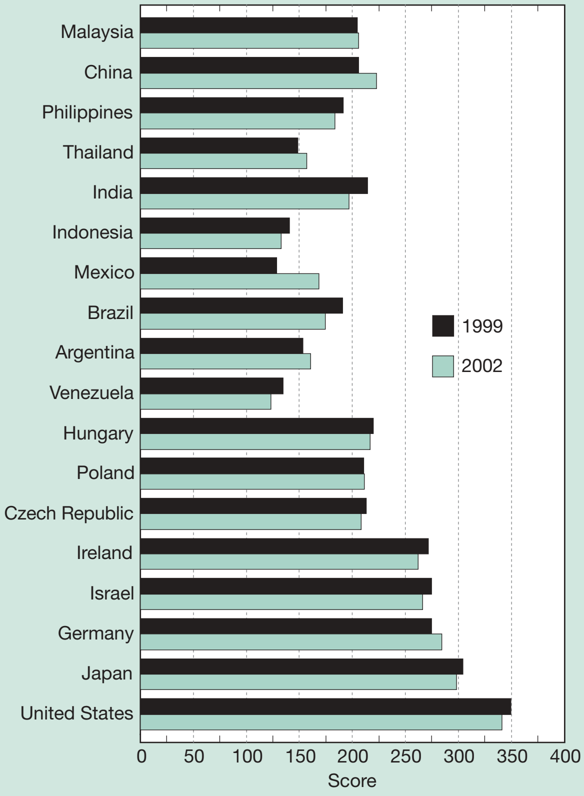
electronics products, which was this indicator's published data variable, was greater than Ireland's, but its overall score was hurt by experts' low rating of the quality of Mexican skilled labor and the existence of indigenous electronics components suppliers.

Findings From the Four Indicators

Based on this set of four leading indicators, Ireland and Israel again earned high scores and appear to be on the path to prominence as exporters of technology products in the global market. Both countries posted similar high scores when these same indicators were developed 3 years ago (figure 6-15 and appendix table 6-6). The latest results show that Ireland led the group of countries examined in two of the four leading indicators and received the second-highest score in a third, socioeconomic infrastructure. Israel ranked first in socioeconomic infrastructure because of its large number of trained scientists and engineers, its highly regarded industrial research enterprise, and its contribution to scientific knowledge. Israel placed second on two of the remaining indicators and third on the other (figure 6-14).

Figure 6-15
Composite scores for four leading indicators in selected countries: 1999 and 2002



NOTE: The four leading indicators are national orientation, socioeconomic infrastructures, technological infrastructure, and productive capacity.

SOURCE: Georgia Technology Research Co., *High Tech Statistics, Preliminary Report*, 2003. See appendix tables 6-5 and 6-6.

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China and Hungary also posted strong scores on several indicators. Hungary ranked third on the indicator identifying nations that are taking action to become technologically competitive and fourth on both the socioeconomic and technological infrastructure indicators. China scored nearly as well and sometimes better than Hungary on the leading indicators, but its scores were not quite as balanced and were likely inflated by its large population.

These indicators provide a systematic way to compare future technological capability for an even wider set of nations than might be available using other indicators. The results highlight how the group of nations that compete in high-technology markets may broaden in the future, as well as reflect the large differences among several emerging and transitioning economies and those considered newly industrialized.

International Trends in Industrial R&D

In high-wage countries such as the United States, one of the ways industries stay competitive in the global marketplace is through innovation (Council on Competitiveness 2001). Innovation provides firms with a comparative advantage through improved products, more efficient production processes, and new product development. This allows high-wage countries to better compete with low-wage nations.

R&D activities are incubators for ideas that can lead to new products, processes, and industries. Although they are not the only source of new innovations, R&D activities conducted in industry-run laboratories and facilities are the source of many important new ideas that have shaped modern technology.[11] Traditionally, U.S. industries that conduct large amounts of R&D meet with greater success in foreign markets than less R&D-intensive industries, and they are more willing to pay their employees higher wages. (See "U.S. Technology in the Marketplace" for discussion of recent trends in U.S. competitiveness in foreign and domestic product markets.)

Moreover, trends in industrial R&D performance are leading indicators of future technological performance. For example, the most recent data show a resurgence in service-sector research and development in the United States and several other advanced nations. The service sector share of U.S. R&D, which was less than 19 percent in 1996, rose to 34 percent in 2000. U.S. manufacturing industries collectively continue to perform nearly two-thirds of the nation's industrial R&D, but cutbacks in R&D by the U.S. aerospace and computer hardware industries mean those sectors' shares of overall R&D have declined, especially in recent years. The following section examines these R&D trends, focusing particularly on growth in industrial R&D activity in the top R&D-performing industries in the United States, Japan, and the EU.[12]

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[11] For a discussion of trends in foreign direct investment in R&D facilities, see chapter 4.

[12] This section uses data from OECD's Analytical Business Enterprise R&D database (July 2002) to examine trends in national industrial R&D performance. This database tracks all R&D expenditures (both defense-and nondefense-related) carried out in the industrial sector, regardless of funding source. Expenditures are expressed in purchasing power parity dollars ($PPP). For an examination of U.S. industrial R&D by funding source and an explanation of $PPP, see chapter 4.

R&D Performance by Industry

The United States, the EU, and Japan are the three largest economies in the industrialized world, and their industries have been leaders of innovation in the international marketplace. An analysis of each nation or region's R&D trends can explain past success, provide insight into future product development, and highlight shifts in national technology priorities.[13]

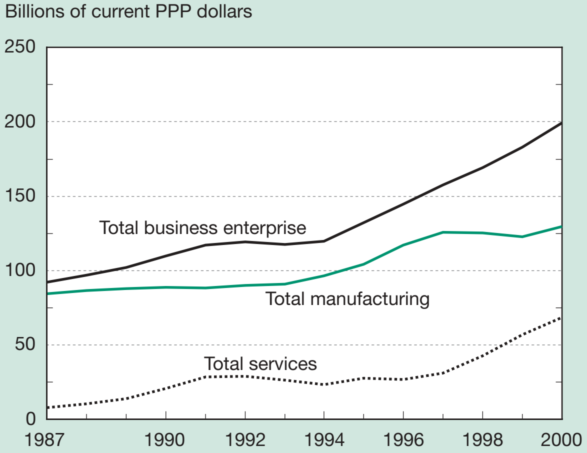
United States

In 1999 and 2000, R&D in U.S. service-sector industries grew at a faster rate than R&D in U.S. manufacturing industries. This surge was similar to the rapid growth experienced between 1987 and 1991 and was again led primarily by computer software firms and firms performing R&D on a contract basis. In 1987, service-sector industries accounted for less than 9 percent of all U.S. industrial R&D. During the next several years, the amount of R&D performed in the service sector raced ahead of that performed by other U.S. manufacturing industries until 1991, when the service sector accounted for nearly one-fourth of all U.S. industrial R&D. Manufacturers regained their position; however, their share inched back to 81 percent of total U.S. industrial R&D by 1996, led by industries making computer hardware, electronics equipment, and motor vehicles (figure 6-16 and appendix table 6-7).

The most recent data for the late 1990s and 2000 show a reemergence of the U.S. service sector as a key performer of industrial R&D. A turnaround that began slowly in 1997 was followed by large increases each year thereafter. The service sector's share of total R&D was less than 19 percent in 1996 but 34 percent by 2000.[14]

U.S. manufacturing industries collectively perform nearly two-thirds of the nation's industrial R&D and include most of the nation's top R&D-performing industries. In 2000, the latest year for which internationally comparable data are available, the industry manufacturing radio, TV, and communication equipment led the nation in industrial R&D.[15] This industry historically has been among the top five performers, but its rise to the top coincided with rapid growth in the telecommunication industry during the late 1990s. Producers of chemical products (primarily pharmaceuticals), scientific instruments, and motor vehicles were also top R&D performers in 2000, as were the industries providing computer services. Computer and office hardware manufacturers fell out of the top five. R&D performance in the U.S. aerospace industry also grew more slowly during the 1990s than in other U.S. industries. The aerospace industry accounted for 19 percent of total U.S. R&D in 1990, but its share dropped nearly every year throughout the decade. By 2000, the U.S. aerospace industry accounted for just 5 percent of total R&D.[16]

Figure 6-16
U.S. industrial R&D performance: 1987–2000



Top industrial R&D performers and share of total industrial R&D (percents)

1990		1995		2000	
Aerospace and other transport equipment	19.2	Total services	21.1	Total services	34.4
Total services	18.9	Chemicals	13.2	Electronic equipment	12.9
Chemicals	12.1	Motor vehicles	11.6	Chemicals	10.7
Computers and office machines	10.7	Electronic equipment	11.4	Instruments	9.6
Motor vehicles	9.3	Aerospace and other transport equipment	8.8	Motor vehicles	9.3

PPP purchasing power parity

SOURCE: Organisation for Economic Co-operation and Development, EAS, ANBERD database, 2002. See appendix table 6-7.

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Japan

The manufacturing sector continues to dominate Japan's industrial R&D performance, as it has throughout the period examined. From 1987 to 2000, the sector consistently accounted for 94–97 percent of all R&D performed by Japanese industry (figure 6-17 and appendix table 6-8). A small expansion in service-sector R&D first seen in the mid-1990s appears to have retreated and, in fact, has declined in recent years. In the early 1990s, Japan's service-sector industries doubled their share of total R&D, reaching 4 percent in both 1996 and 1997. However, R&D performed by Japan's service sector has declined each year since, returning to early-1990s levels. Service-sector R&D in 2000 accounted for just 2.1 percent of Japan's industrial R&D performance.

The top industrial R&D performers in Japan during 1987–2000 reflect the country's long-standing emphases on electronics technology (including consumer electronics

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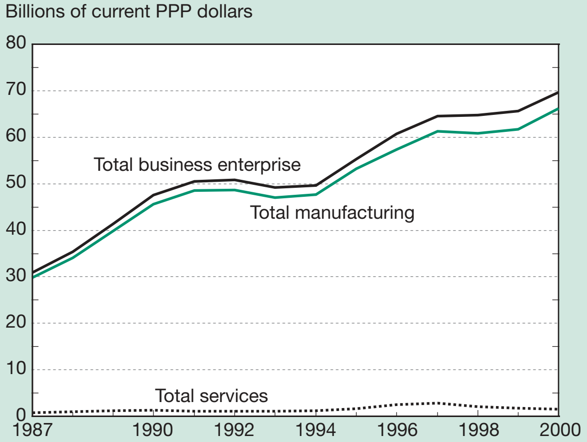
[13] Industry-level data are occasionally estimated to provide a complete time series for the 1987–2000 period.

[14] Part of the apparent growth is due to the reclassification of some firms that were previously identified as manufacturers under the SIC. Those firms have been reclassified as service industries under the NAICs.

[15] Some of the trends reported here differ from those reported in chapter 4 due to the reclassification of U.S. data to conform with the international industry classification system used by OECD.

[16] One of the recommendations made in a recent report to the President and the Congress of the United States by the Commission on the Future of the United States Aerospace Industry calls for a renewed focus on long-term research (Presidential Commission 2002).

Figure 6-17
Japan industrial R&D performance: 1987–2000



Top industrial R&D performers and share of total industrial R&D (percents)

1990		1995		2000	
Electronic equipment	15.7	Electronic equipment	17.5	Electronic equipment	18.8
Chemicals	15.3	Chemicals	16.5	Chemicals	15.0
Motor vehicles	13.8	Motor vehicles	12.2	Motor vehicles	12.4
Electrical machines	10.8	Electrical machines	11.0	Computers and office machines	10.8
Computers and office machines	9.7	Computers and office machines	9.0	Electrical machines	9.8

PPP purchasing power parity

SOURCE: Organisation for Economic Co-operation and Development, EAS, ANBERD database, 2002. See appendix table 6-8.

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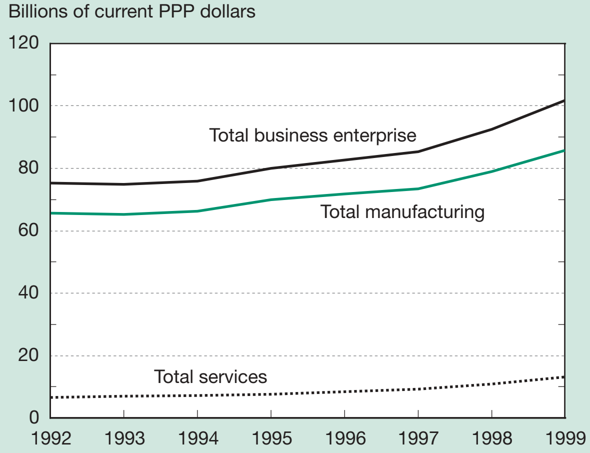
and audiovisual equipment), motor vehicles, and electrical machinery. Japan's electronics equipment industry was the leading R&D performer throughout most of the period, accounting for nearly 19 percent of all Japanese industrial R&D in 2000. Japan's chemical industry, also a leading performer in 2000, accounted for 15 percent of the country's industrial R&D, second only to the electronics equipment industry. Producers of motor vehicles, computer hardware, and electrical machinery round out the remaining top R&D performers. In contrast, U.S. machinery producers consistently dropped in rank among the top U.S. R&D performers since the early 1970s.

European Union

As in the United States and Japan, manufacturing industries perform the bulk of industrial R&D in the 15-nation EU. The EU's industrial R&D appears to be less concentrated in specific industries than R&D in the United States, but more so than in Japan. Manufacturers of chemicals and chemical products, electronics equipment, and motor vehicles consistently were among the top five industrial R&D performers in the EU (figure 6-18 and appendix table 6-9). The aerospace industry (other transportation) and the service sector round out the group. According to the latest data available for the EU, Germany led the EU in R&D in many of the major manufacturing industries, including chemical products, motor vehicles, communication equipment, and computer hardware. The United Kingdom led in pharmaceutical and service-sector R&D.[17]

Figure 6-18
European Union industrial R&D performance: 1992–99



Top industrial R&D performers and share of total industrial R&D (percents)

1992		1995		1999	
Chemicals	19.7	Chemicals	20.1	Chemicals	19.9
Motor vehicles	13.8	Motor vehicles	13.8	Motor vehicles	16.1
Electronic equipment	10.8	Electronic equipment	12.0	Electronic equipment	13.5
Aerospace and other transport equipment	10.7	Aerospace and other transport equipment	9.5	Total services	13.0
Total services	8.3	Total services	9.4	Aerospace and other transport equipment	8.6

PPP purchasing power parity

SOURCE: Organisation for Economic Co-operation and Development, EAS, ANBERD database, 2002. See appendix table 6-9.

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Service-sector R&D has steadily increased each year and accounted for 13 percent of total EU industrial R&D in 1999, nearly equal to that of the EU's electronic equipment industry and almost double that of the EU's aerospace industry. Large increases in service-sector R&D are apparent in many EU countries, especially Italy, where service-sector R&D made up about 24 percent of industrial R&D from 1999 to 2001, and the United Kingdom, where it accounted for 21 percent of R&D in 1999.

Patented Inventions

Inventions are of great economic importance to a nation because they often result in new or improved products, more efficient manufacturing processes, or entirely new industries. To foster inventiveness, nations assign property rights to

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[17] The latest calendar-year data were 2001 for Italy, 2000 for Germany and the United Kingdom, and 1999 for France.

inventors in the form of patents. These allow the inventor to exclude others from making, using, or selling the invention. Inventors obtain patents from government-authorized agencies for inventions judged to be new, useful, and not obvious.

Although the U.S. Patent and Trademark Office (PTO) grants several types of patents, this discussion is limited to utility patents, which are commonly known as patents for inventions. They include any new and useful (or improved on) method, process, machine, device, manufactured item, or chemical compound.

Patenting indicators have several well-known drawbacks, including:

- **Incompleteness**—many inventions are not patented at all, in part because laws in some countries already provide for the protection of industrial trade secrets.
- **Inconsistency across industries and fields**—the propensity to patent differs by industry and technology area.
- **Inconsistency in importance**—the importance of patented inventions can vary considerably.

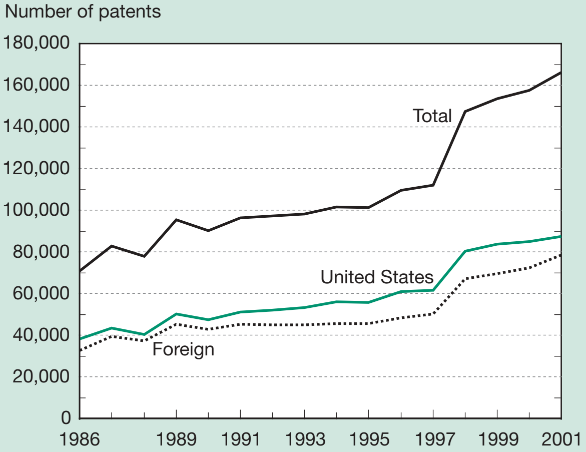
Despite these limitations, patent data provide useful indicators of technical change and serve as a way to measure inventive output over time.[18] In addition, information about foreign inventors seeking U.S. patents enables the measurement of inventiveness in foreign countries and can serve as a leading indicator of new technological competition.[19] (See sidebar, "New Database May Help to Identify Important Inventions.")

U.S. Patenting

More than 166,000 patents were issued in the United States in 2001, 5 percent more than in 2000. This record number extends a period of nearly uninterrupted growth that began in the late 1980s. Since then, growth in U.S. patenting has been steady, but slower[20] (figure 6-19 and appendix table 6-10).

Figure 6-19

U.S. patents granted, by residence of inventor: 1986–2001



SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, special tabulations, 2002. See appendix table 6-10.

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Patents Granted to U.S. Inventors

Some observers have at times expressed concern that any downward trend in the number of patents issued to U.S. inventors could indicate a decline in U.S. inventiveness. However, the share of total U.S. patents granted to U.S. inventors has been fairly stable over the years, fluctuating within a very narrow range (52–56 percent). A small decline during the mid-1980s rebounded by the end of the decade as patenting by U.S. inventors increased and outpaced patenting by foreign inventors. Since peaking at 56 percent in 1996, the share of U.S. patents granted to and held by U.S. resident inventors has declined slightly. In 2001, U.S. inventors were awarded nearly 88,000 new patents, or about 53 percent of the total patents granted by the United States. The increase in U.S. patents granted to foreigners may simply reflect the attractiveness of the U.S. market for new products and the growing capacity for global technological innovation.

Inventors who work for private companies or the Federal Government commonly assign ownership of their patents to their employers; self-employed or independent inventors typically retain ownership of their patents. Therefore, examining patent data by the owner's sector of employment can provide a good picture of a sector's inventive work. Corporations owned 82 percent of patents granted to U.S. entities (including other U.S. organizations, the Federal Government, and independent U.S. resident inventors) in 2001.[21] This percentage has gradually increased over time. From 1987 to 1997, corporate-owned patents accounted for between 77 and 79 percent of total U.S.-owned patents. Since 1997, corporations have generally increased their share of

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[18] For a survey of literature related to this point, see Z. Griliches. Patent statistics as economic indicators: A survey. *Journal of Economic Literature* 28 (December): 1661–707.

[19] It should also be noted that there is concern that patents and other forms of exclusive ownership of intellectual property may discourage research into, communication about, and diffusion of new technologies. The question arises whether, in some cases, the extension of intellectual property rights has gone too far. To provide answers and guide intellectual property right (IPR) policy over the next decade and beyond, the Science, Technology and Economic Policy Board (STEP) of the National Research Council (NRC) has undertaken a project to review the purposes of the IPR legal framework and assess how well those purposes are being served. The board will identify whether there are current or emerging problems of inadequate or over-protection of IPRs that need attention and will commission research on some of these topics. The report is due out later in 2003.

[20] The number of U.S. patents granted jumped by 32 percent from 1997 to 1998. Although patent applications had been rising before that, the PTO attributes much of the increase in 1998 to greater administrative efficiency and the hiring of additional patent examiners.

[21] U.S. universities and colleges owned about 1.9 percent of U.S. utility patents granted in 2001. The U.S. PTO counts these as being owned by corporations. For further discussion of academic patenting, see chapter 5.

New Database May Help to Identify Important Inventions

One criticism of any attempt to analyze national inventive activity by simply counting patents is the inability of such counts to differentiate between minor inventions and highly important inventions. A new database developed through an international partnership of patent offices in the United States, Europe, and Japan provides a new tool for patent researchers that addresses this problem.* This new dataset counts only inventions for which patent protection is sought in three important markets: the United States, Europe, and Japan. Each invention that satisfies this condition forms one triadic patent family.

The high cost of filing for patents in three separate patent offices makes triadic patent families a more accurate measure of important inventions than simple patent counts. In most cases, only economically valuable inventions will justify the costs associated with filing patents in all three locations. For example, application fees alone can exceed several thousand dollars, not counting related legal costs. In total, the costs for an inventor to file for patent protection in his or her country of residence are significant. The costs to file in other countries are even greater.

Table 6-2 presents data generated from the new database. Counts of triadic patent families, sorted by the inventor's residence for selected countries, are listed by priority year—that is, the year of the first patent filing. It covers the period 1988–98 and shows that the United States has been the leading producer of important inventions in every year except 1988. Inventors residing in EU countries produced nearly as many important inventions as did inventors living in the United States, and they produced more than the U.S. inventors in 1988. Within the EU, Germany had more triadic patent inventors than the next three leading European countries—France, the United Kingdom, and the Netherlands. Inventors residing in Japan produced only slightly fewer important inventions than inventors in the United States or the EU. However, given its much lower population, Japan's inventive productivity would easily exceed that of the United States or the EU if the number of inventions per capita was used as the basis for comparison.

When the data are examined by the patent applicant's or owner's country of residence, the overall rankings for the United States, the EU, and Japan do not change, although the U.S. share increases, the EU share decreases, and Japan's stays about the same. The shift in shares between the United States and the EU is nearly identical, and it appears that the percentage increase in the U.S. share comes almost completely from the EU. The difference in country shares when triadic patent families are sorted by the owner's residence as opposed to the inventor's residence suggests that U.S. companies (corporations own most triadic patent families) employ or otherwise purchase ownership of more European innovations than European firms employ or otherwise purchase ownership of U.S. innovations. Another explanation might be that U.S. companies' European operations are more R&D- or discovery-oriented than European operations in the United States. The near constant shares for Japan tend to reinforce the image of Japanese firms as more insular and tending to rely on the discoveries of native inventors.

Table 6-2
Triadic patent families, by inventor and applicant (owner) place of residence and priority year: 1988–98

Place of residence	Total	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
	Number											
World total of triadic patent families	364,335	30,814	33,360	32,919	30,677	30,669	31,454	32,243	35,161	37,679	37,630	31,729
	Percent											
Inventor												
United States	34.9	33.0	33.0	34.4	34.9	36.2	35.4	34.8	34.3	33.9	35.6	39.1
European Union	31.6	33.5	31.7	30.2	30.5	31.3	31.8	33.6	32.7	32.8	31.0	28.3
Japan	27.5	28.3	30.2	30.3	29.1	26.7	26.8	25.3	26.5	26.9	26.6	26.2
Applicant												
United States	39.4	37.9	37.5	38.8	39.4	40.8	40.3	40.0	38.8	38.4	39.3	42.2
European Union	27.7	29.4	28.0	26.7	26.7	27.3	27.7	29.4	28.6	28.5	27.5	25.3
Japan	27.3	28.0	30.0	29.9	28.9	26.5	26.6	24.9	26.3	26.8	26.7	26.2

NOTE: A triadic patent family is formed when patent applications for the same invention are filed in Europe, Japan, and the United States.

SOURCE: Organisation for Economic Co-operation and Development/World Intellectual Property Organization, Triadic Patent Families, unpublished tabulations.

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*The project is a collaboration among OECD, the National Science Foundation, the European Union, the World Intellectual Property Organization, patent offices in the United States and Japan, and the European Patent Office. The database was developed by and is housed at OECD.

total patents, rising to 80 percent in 1999, 81 percent in 2000, and 82 percent in 2001.

Individuals (independent inventors) are the second-largest group of U.S. patent owners. Before 1988, individuals owned, on average, 23 percent of all patents granted to U.S. entities.[22] This figure has trended downward since then, to a low of 17 percent in 2001. The Federal Government's share of patents averaged 3 percent from 1963 to 1987, eventually falling to 1.1 percent in 1999.[23] Its share remained at about 1 percent in 2000 and 2001.[24]

Patents Granted to Foreign Inventors

Patents issued to foreign inventors represented 47 percent of all patents granted by the United States in 2001, a share that has increased slightly since 1999.[25] During much of the 1980s, growth in the number of patents issued to non-U.S. entities outpaced growth in the number of patents granted to U.S. inventors. This trend peaked in 1987 and 1988, when patents granted to foreign inventors accounted for 48 percent of all U.S. patents. (See sidebar, "Top Patenting Corporations.") From 1990 until 1996, however, the trend reversed: U.S. inventor patenting activity increased at a faster pace than did foreign inventors', which dropped the foreign share of all patents to 44 percent. Over that time, Japan and Germany accounted for about 56 percent of all U.S. patents granted to foreign inventors. The top four countries (Japan, Germany, France, and the United Kingdom) accounted for about 72 percent of U.S. patents awarded to foreign residents since 1963 (figure 6-20).

Although patenting by inventors from leading industrialized countries has leveled off or declined in recent years, some Asian economies, particularly Taiwan and South Korea, have stepped up their patenting activity in the United States and are proving to be strong inventors of new technologies.[26] Between 1963 (the year data first became available) and 1987, Taiwan

Top Patenting Corporations

A review of corporations that received the largest number of patents in the United States during the past 25 years illustrates Japan's technological transformation over a relatively short period. In 1973, no Japanese companies ranked among the top 10 corporations seeking patents in the United States. In 1983, however, 3 of the top 10 companies were Japanese, and by 1993, Japanese companies outnumbered U.S. companies. Seven of the top 10 companies were Japanese in 1996. The most recent data (2001) show 1 South Korean company (Samsung Electronics Company), 2 U.S. companies, and 7 Japanese companies among the top 10 (table 6-3). Samsung ranked fourth among foreign corporations patenting in the United States in 1999, after ranking 17th just 2 years earlier. South Korea's U.S. patent activity emphasizes computer, television and communication equipment, and power generation technologies.

IBM was awarded more patents than any other U.S. organization in 2001, the ninth consecutive year that the company earned this distinction. Micron Technology, Inc., joined the top 10 in 2000 and in 2001 was awarded 1,643 patents, nearly one-quarter more than it received just a year earlier. IBM and Micron were the only U.S. companies to make the top 10.

Table 6-3
Top patenting corporations: 1977–96 and 2001

Company	Patents
1977–96	
General Electric Corp.	16,206
International Business Machines Corp.	15,205
Hitachi Ltd.	14,500
Canon Kabushiki Kaisha	13,797
Toshiba Corp.	13,413
Mitsubishi Denki Kabushiki Kaisha	10,192
U.S. Philips Corp.	9,943
Eastman Kodak Co.	9,729
AT&T Corp.	9,380
Motorola, Inc.	9,143
2001	
International Business Machines Corp.	3,411
NEC Corp.	1,953
Canon Kabushiki Kaisha	1,877
Micron Technology, Inc.	1,643
Samsung Electronics Co., Ltd.	1,450
Matsushita Electric Industrial Co., Ltd.	1,440
Sony Corp.	1,409
Hitachi Ltd.	1,271
Mitsubishi Denki Kabushiki Kaisha	1,184
Fujitsu Ltd.	1,166

SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, special tabulations, November 2002.

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[22] Before 1988, data are provided as a total for the period 1963–87. In U.S. PTO statistical reports, the ownership category breakout is independent of the breakout by country of origin.

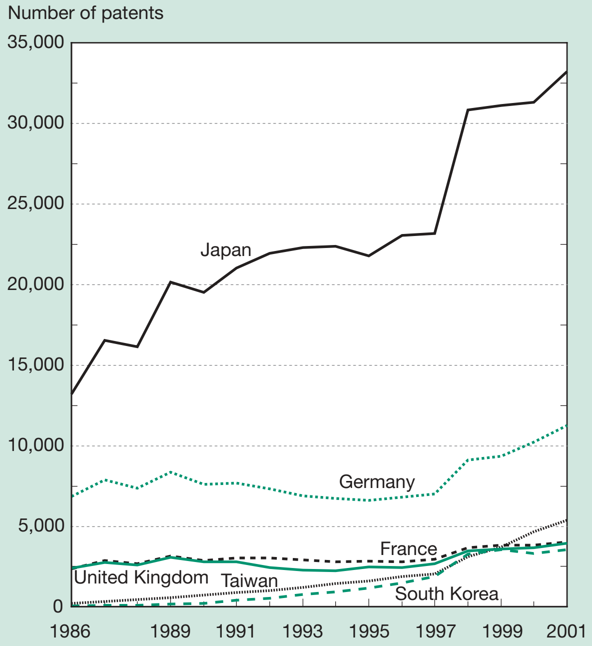
[23] Federal inventors frequently obtain a statutory invention registration (SIR) rather than a patent. SIR is not ordinarily subject to examination and is less costly to obtain than a patent. Also, SIR gives the holder the right to use the invention but does not prevent others from selling or using it.

[24] The Bayh-Dole Act of 1980 (PL 96-517) permitted government grantees and contractors to retain title to inventions resulting from federally supported R&D and encouraged the licensing of such inventions to industry. The Stevenson-Wydler Technology Innovation Agreement of 1980 (PL 96-480) made the transfer of federally owned or originated technology to state and local governments and to the private sector a national policy and the duty of government laboratories. The act was amended by the Federal Technology Transfer Act of 1986 (PL 99-502) to provide additional incentives for the transfer and commercialization of federally developed technologies. In April 1987, Executive Order 12591 ordered executive departments and agencies to encourage and facilitate collaborations among Federal laboratories, state and local governments, universities, and the private sector, particularly small business, to aid technology transfer to the marketplace. In 1996, Congress strengthened private-sector rights to intellectual property resulting from these partnerships. See chapter 4 for a further discussion of technology transfer and other R&D collaborative activities.

[25] Corporations account for about 86 percent of all foreign-owned U.S. patents.

[26] Some of the decline in U.S. patenting by inventors from the leading industrialized nations may be attributed to movement toward European unification, which has encouraged wider patenting within Europe.

Figure 6-20
U.S. patents granted to foreign inventors in selected countries, by residence of inventor: 1986–2001



NOTE: Selected countries/economies are the top six recipients of U.S. patents during 2001.

SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, special tabulations, 2002. See appendix table 6-10.

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received just 1,293 U.S. patents. During the 14-year period since then, Taiwan was awarded nearly 29,000 U.S. patents. U.S. patenting activity among inventors from South Korea shows a similar growth pattern. Before 1987, South Korea received just 343 U.S. patents; since that time, South Korea has been awarded more than 21,000 new patents. The latest data indicate that Taiwan has moved ahead of France and the United Kingdom to become the third most active residence of foreign inventors who obtain patents in the United States. In 2000 and 2001, the top five countries receiving patents from the United States were Japan, Germany, Taiwan, France, and the United Kingdom.

Trends in Applications for U.S. Patents

The review process leading up to the official grant of a new patent takes approximately 2 years, on average. Consequently, examining year-to-year trends in the number of patents granted does not always show the most recent changes in patenting activity. The number of patent applications filed with the U.S. PTO are examined to obtain an earlier, albeit less certain, indication of changes to patterns of inventiveness.

Patent Applications From U.S. and Foreign Inventors

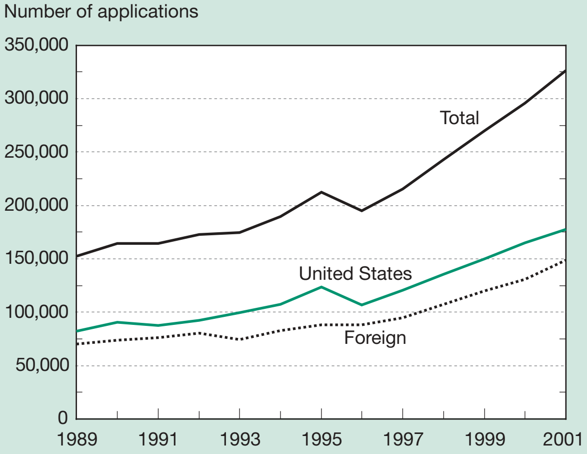
Applications for U.S. patents reached 326,500 in 2001, about 10 percent more than in 2000. Applications rose by a similar percentage in 2000. These latest data add to what has been nearly a decade of annual increases (figure 6-21 and appendix table 6-11).

Patent applications from U.S. residents made up 56 percent of all applications in 2000, a share maintained since 1997. In 2001, this share declined slightly, to 54 percent. Because patents granted to foreign inventors generally accounted for about 45–47 percent of total U.S. patents granted, the success rate for foreign applications appears to be about the same or slightly higher than that of U.S. inventor applications.[27]

Over time, residents of Japan have received more patents than residents of any other country. They accounted for 40–48 percent of U.S. patent applications made by foreign residents, more than twice that of Germany, which had the next most active group of applicants. Japan's share slipped only in the late 1990s, falling to a decade low of 40 percent in 1999. Since then, its share has increased. The German share has generally exhibited a downward trend, falling from a high of 16 percent in 1989 to about 13 percent in 2000 and 2001.

Although patent filings by inventors from the leading industrialized countries leveled off or began to decline, other countries, particularly Asian countries, stepped up their patenting activity in the United States. This is especially true for Taiwan and South Korea, and data on recent

Figure 6-21
U.S. patent applications, by residence of inventor: 1989–2001



SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, special tabulations, 2003. See appendix table 6-11.

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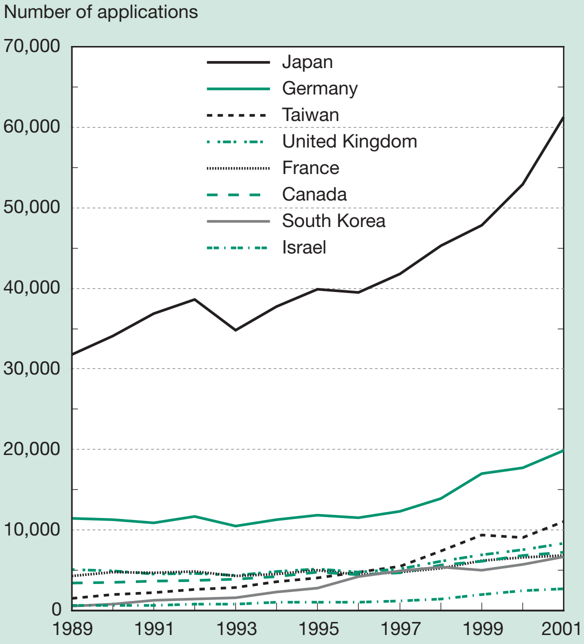
[27] This may not be surprising because the additional expenses associated with applying for a patent in a foreign market will likely discourage weak foreign applications.

patent applications indicate that the rising trend in U.S. patents granted to residents of these two Asian economies is likely to continue. Since 1997, residents of Taiwan and South Korea distinguished themselves in the number of applications submitted, applying for enough patents to replace France and Canada in the top five foreign sources seeking U.S. patents. Residents of Taiwan moved further up the list, to third, in 1998, and in 1999 applied for more than 9,000 new patents. This was an increase of 27 percent from the previous year and 2,400 more applications than were made by residents from the fourth-ranked United Kingdom. U.S. patent applications by Taiwanese inventors dropped by about 4 percent in 2000 but resumed double-digit growth in 2001. If recent patents granted to residents of Taiwan are indicative of the technologies awaiting review, many of these applications will be for new computer and electronic inventions. After slowing somewhat in 1999, U.S. patent applications from South Korean inventors picked up, increasing by 13 percent in 2000 and 18 percent in 2001 (figure 6-22).

Equally impressive was growth in patent applications by inventors from Israel, India, Finland, Belgium, and China. Data show dramatic increases over the past several years and provide yet another indication of the ever-widening community of nations active in global technology development and diffusion.

Figure 6-22
U.S. patent applications filed by selected foreign inventors, by residence of inventor: 1989–2001



SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, special tabulations, 2003. See appendix table 6-11.

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Technical Fields Favored by Foreign Inventors

A country's inventors and the distribution of its patents by technical area is a reliable indicator of both the country's technological strengths and its focus on product development. Patent activity in the United States by inventors from foreign countries can be used to identify a country's technological strengths as well as U.S. product markets likely to see increased competition. This section discusses the key technical fields favored by U.S. resident inventors and inventors from the top five foreign countries obtaining patents in the United States.[28]

Fields Favored by U.S. and Leading Foreign Resident Inventors

Although U.S. patent activity encompasses a wide spectrum of technology and new product areas, corporate patenting patterns reflect activity in several technology areas that have already contributed much to the nation's economic growth. In 2001, for example, corporate patent activity indicated U.S. technological strengths in business methods, medical and surgical devices, electronics, telecommunication, and biotechnology (table 6-4).

The 2001 data also show Japan's continued emphasis on photocopying, photography, and office electronics technology, as well as its broad range of U.S. patents in communication technology. From improved information storage technology for computers to wave transmission systems, Japanese inventors have earned U.S. patents in areas that aid in the processing, storage, and transmission of information.

German inventors continue to develop new products and processes in areas associated with heavy manufacturing, a field in which they have traditionally maintained a strong presence. The 2001 U.S. patent activity index shows that Germany emphasizes inventions for motor vehicles, printing, switches, and material-handling equipment.

In addition to inventions for traditional manufacturing applications, British patent activity is high in aeronautics, biotechnology, and chemistry (appendix table 6-12). Like the British, the French are quite active in patent classes associated with manufacturing applications and aeronautics (appendix table 6-13). They share the emphasis of U.S. and British inventors in biotechnology.

As recently as 1980, Taiwan's U.S. patent activity was concentrated in the area of toys and other amusement devices. By the 1990s, Taiwan was active in communication technology, semiconductor manufacturing processes, and internal combustion engines. Data from 2001 show that

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[28] Information in this section is based on U.S. PTO's classification system, which divides patents into approximately 400 active classes. With this system, patent activity for U.S. and foreign inventors in recent years can be compared using an activity index. For any year, the activity index is the proportion of patents in a particular class granted to inventors resident in a specific country divided by the proportion of all patents granted to inventors resident in that country. Because U.S. patenting data reflect a much larger share of patenting by individuals without corporate or government affiliation than do data on foreign patenting, only patents granted to corporations are used to construct the U.S. patenting activity indices.

Table 6-4
Top 15 most emphasized U.S. patent classes for corporations from United States, Japan, and Germany: 2001

Rank	United States	Japan	Germany
1	Business practice, data processing	Photocopying	Clutches and power-stop control
2	Surgery: light, thermal, and electrical applications	Information storage and retrieval	Rotary shafts
3	Computers and digital processing systems	Television signal processing	Brake systems
4	Surgery instruments	Photography	Printing
5	Data processing, file management	Electrophotography	Winding, tensioning, or guiding devices
6	Digital processing systems	Liquid crystal cells	Machine element or mechanism
7	Computer memory	Facsimile	Land vehicles, bodies and tops
8	Data processing software	Incremental printing of symbolic information	Magnetically operated switches
9	Surgery (medicators and receptors)	Electric lamp and discharge devices	Metal forming
10	Prosthesis	Typewriting machines	Brakes
11	Wells	Electrical generators	Land vehicles
12	I/O digital processing systems	Radiation imagery chemistry	Joints and connections
13	Boring or earth penetrating apparatus	Ceramic compositions	Internal combustion engines
14	Multicellular living organisms	Wave transmission lines and networks	Fluid sprayers
15	Digital processing, support	Optics systems, including communication	Electrical transmission systems

I/O input/output

NOTES: Rank is based on patenting activity of nongovernment U.S. or foreign organizations, which are primarily corporations. Patenting by individuals and governments is excluded.

SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, 2002.

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Taiwan's inventors also became active in other areas, adding electrical systems, semiconductors, and computer hardware technologies to their technology portfolio.

U.S. patenting by South Korean inventors also reflects that country's rapid technological development. The 2001 data show that South Korean inventors are currently patenting heavily in television technologies and a broad array of computer technologies that include devices for dynamic and static information storage, data generation and conversion, error detection, and display systems (table 6-5).

Patent Activity Outside the United States

In most countries, nonresident (foreign) inventors account for a much larger share of total patent activity than is true in the United States.[29] When foreign patent activity in the United States is compared with that in nine other countries, only Japan and Russia consistently showed lower activity levels (figure 6-23 and appendix table 6-14). Data from the patent offices in Brazil, Italy, and the United Kingdom all show that about 80 percent of patents granted in those countries go to nonresident inventors.[30] Even higher levels of nonresident patenting occur in Canada and Mexico (more than 90 percent in 1999 and 2000). Although much attention is given to the level of nonresident patent activity in the United States, it has remained farily stable over the past 10 years, accounting for about 44–47 percent of all U.S. patents issued.

Data from the World Intellectual Property Organization (WIPO), which includes patent data from most patent-granting countries, show the global reach of U.S., Japanese, and German inventors who patent their inventions in other countries. In 1999 and 2000, U.S. inventors made up the largest group of foreign inventors seeking patents in the countries neighboring the United States and in major markets in Asia, Europe, and Latin America. U.S. inventors also received more patents than other nonresident inventors in Japan, India, Brazil, Mexico, France, Germany, Italy, and the United Kingdom (figure 6-24). Japanese-resident inventors, who consistently account for the largest percentage of U.S. patents granted to nonresident inventors, also patent successfully in other parts of the world. In addition to their success patenting in the United States, Japanese-resident inventors lead all foreign inventors patenting in China and South Korea, and they follow only U.S. inventors in the United Kingdom and Canada. Germany, whose inventors also have a long tradition of patenting new inventions in the United States, actively patent in India, Japan, Brazil, Mexico, and other large European markets.

These data underscore the importance that corporations and other owners of new technologies—through seeking to protect their intellectual property—place on national patent systems. They also show the extent to which both advanced and developing nations depend on the diffusion of new technologies from around the world.

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[29] Patents granted for an invention in one country do not offer any protection under another country's intellectual property laws.

[30] This discussion is based on data from the World Intellectual Property Organization in Geneva, Switzerland, which includes patenting data from most patent granting countries. These data were compiled by Mogee Research & Analysis, LLC.

Table 6-5
Top 15 most emphasized U.S. patent classes for corporations from South Korea and Taiwan: 2001

Rank	South Korea	Taiwan
1	Liquid crystal cells, elements, and systems	Semiconductor device manufacturing process
2	Static information storage and retrieval	Electrical connectors
3	Electric lamp and discharge systems	Circuit makers and breakers
4	Television	Electrical systems and devices
5	Semiconductor device manufacturing process	Active solid-state devices
6	Dynamic magnetic information storage or retrieval	Supports
7	Television signal processing for recording	Heat exchange
8	Miscellaneous active electrical nonlinear devices	Abrading
9	Electric lamp and discharge devices	Rotary expansible chamber devices
10	Pulse or digital communications	Special receptacle or package
11	Electrophotography	Typewriting machines
12	Active solid-state devices	Radiation imagery chemistry
13	Computers	Brushing, scrubbing, and general cleaning
14	Electronic digital logic circuitry	Cleaning
15	Computer graphics	Battery or capacitor charging

NOTE: Rank is based on patenting activity of nongovernmental organizations, which are primarily corporations. Patenting by individuals and governments is excluded.

SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, 2002.

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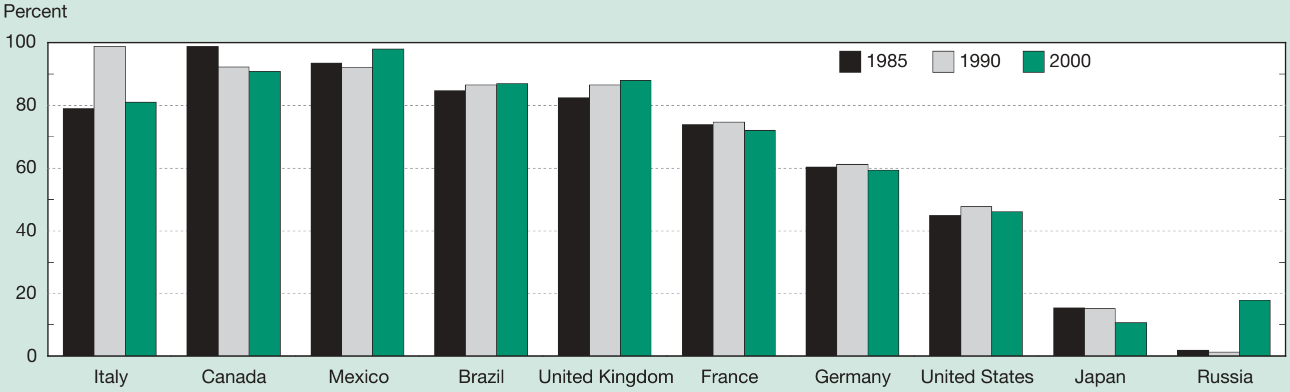
Figure 6-23
Patents granted to nonresident inventors in selected countries: 1985, 1990, and 2000



NOTE: Data for Russia in 1985 and 1990 reflect data for the Soviet Union.

SOURCE: World Intellectual Property Organization, industrial property statistics, http://www.wipo.org/ipstats/en, selected years. See appendix table 6-14.

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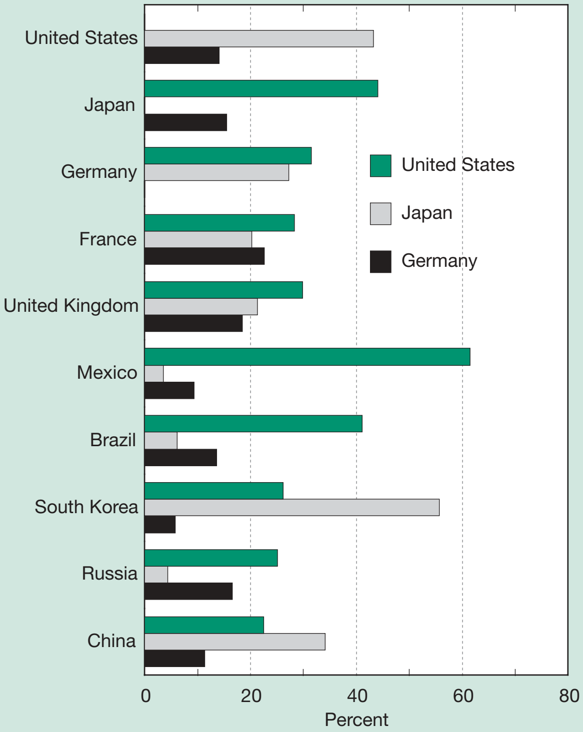
Venture Capital and High-Technology Enterprise

Venture capitalists typically make investments in small, young companies that may not have access to public or credit-oriented institutional funding. Such investments can be long term and high risk and, in the United States, almost always include hands-on involvement in the firm by the venture capitalist. This money can aid the growth and development of small companies and new products and technologies, and it is often an important source of funds used in the formation and expansion of small high-technology companies. This is of special interest to the S&E field, as small businesses play a vital role in the U.S. economy and have become important employers of recent S&E graduates (National Venture Capital Association 2002).

For most of the 1990s, computer technology businesses engaged in hardware or software production and related services and medical and health care companies were the leading recipients of venture capital in the United States. This pattern changed significantly in 1999, when Internet-specific businesses emerged in the marketplace.

This section examines venture capital investment patterns in the United States since 1980, with special emphasis given to a comparison of trends in 1999 and 2000 (hereafter called the *bubble years*) with trends in 2001 and 2002 (hereafter

Figure 6-24
Patents granted to residents of United States, Japan, and Germany in selected countries: 2000



NOTES: Data represent inventor share of all foreign-resident patents granted. Data for Brazil are from 1999.

SOURCE: World Intellectual Property Organization, industrial property statistics, selected years. See appendix table 6-14.

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Table 6-6
New capital committed to U.S. venture capital funds: 1980–2002
(Billions of U.S. dollars)

Year	New capital
1980	2.1
1981	1.6
1982	1.7
1983	4.1
1984	3.1
1985	4.0
1986	3.9
1987	4.4
1988	4.9
1989	5.6
1990	3.5
1991	2.1
1992	5.4
1993	3.9
1994	7.8
1995	10.0
1996	12.2
1997	19.0
1998	29.7
1999	62.8
2000	105.8
2001	37.9
2002	7.7

SOURCE: Thomson Venture Economics, special tabulations, June 2003.

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called the *postbubble period*). It discusses changes in the overall level of investment, the technology areas U.S. venture capitalists find attractive, and the types of investments made.[31]

U.S. Venture Capital Resources

Several years of high returns on venture capital investments during the early 1990s led to a sharp increase in investor interest. The latest data show that new commitments rose vigorously each year from 1996 through 2000, with the largest 1-year increase in 1999 (table 6-6). Investor commitments to venture capital funds jumped to $62.8 billion that year, a 111 percent gain from 1998. By 2000, new commitments reached $105.8 billion, more than 10 times that recorded in 1995. Quickly, venture capital emerged as a key source of financing for small innovative firms. Evidence of a slowdown emerged in 2001 when new commitments declined for the first time in 10 years.[32] Commitments fell by more than 64 percent that year, to $37.9 billion. Still, this sharply reduced total was quite large when compared with capital investments during the prebubble years. Another sharp drop in 2002 reduced the amount of new money coming into venture capital funds to only $7.7 billion, a level not seen since 1994.

The pool of money managed by venture capital firms grew dramatically over the past 20 years as pension funds became active investors following the U.S. Department of Labor's clarification of the "prudent man" rule in 1979.[33] In fact, pension funds became the single largest supplier of new funds. During the entire 1990–2002 period, pension funds supplied about 44 percent of all new capital. Endowments and foundations were the second-largest source, supply-

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[31] Data presented here are compiled by Thomson Venture Economics for the National Venture Capital Association. These data are obtained from a quarterly survey of venture capital practitioners that include independent venture capital firms, institutional venture capital groups, and recognized corporate venture capital groups. Information is at times augmented by data from other public and private sources.

[32] According to recent reports from the National Venture Capital Association, new money coming into venture capital funds slowed down during the last quarter of 2000, following several quarters of lackluster returns to investors in venture capital funds. See "Venture Capital Fundraising Slows in Fourth Quarter, But Hits New Record for the Year," NVCA February 22, 2001.

[33] Under the Department of Labor "Prudent Person"standard, "A fiduciary must discharge his or her duties in a prudent fashion." For pension fund managers, the standard emphasizes how prudent men balance both income and safety as they choose investments. The web site www.investorwords.com describes the Prudent Man Rule as the fundamental principle for professional money mangement stated by Judge Samuel Putnam in 1830 (Supreme Court of Massachusetts in *Harvard College v. Armory*): "Those with responsibility to invest money for others should act with prudence, discretion, intelligence, and regard for safety of capital as well as income."

ing 17 percent of committed capital, followed closely by financial and insurance companies at 16 percent (table 6-7). California, New York, and Massachusetts together account for about 65 percent of venture capital resources, as venture capital firms tend to cluster around locales considered to be hotbeds of technological activity, as well as in states where large amounts of R&D are performed (Thomson Financial Venture Economics 2002).

Boom and Bust in New Venture Capital Commitments

High returns on venture capital investments during the 1990s made the funds attractive for risk-tolerant investors. Starting in 1994, the amount of new capital raised exceeded that disbursed by the industry, leading to a large pool of money available for investments in new or expanding firms. As early as 1990, firms producing computer software or providing computer-related services began receiving large amounts of venture capital (appendix table 6-15). Software companies received 17 percent of all new venture capital disbursements in 1990, more than any other technology area. This figure fluctuated between 12 and 21 percent thereafter. Communication companies also attracted large amounts of venture capital during the 1990s, receiving from 12 to 21 percent of total disbursements. Medical and health care-related companies received a high of almost 21 percent of venture capital in 1992 before dropping to just 5 percent in 1999.

In the late 1990s, the Internet emerged as a business tool, and companies developing Internet-related technologies drew venture capital investments in record amounts. Beginning in 1999, investment dollars disbursed to Internet companies were classified separately, whereas before 1999, some of these funds were classified as going to companies involved in computer hardware, computer software, or communication technologies. Internet-specific businesses involved primarily in online commerce were the leading recipients of venture capital in the United States during the bubble years. They collected more than 40 percent of all venture capital funds invested in each of those years. Software and software services companies received 15–17 percent of disbursed venture capital funds. Communication companies (including telephone, data, and wireless communication) were a close third with 14–15 percent.

The U.S. stock market suffered a dramatic downturn after its peak in early 2000, with the sharpest drops in the technology sector. Led by a dot.com meltdown, technology stock valuations generally plummeted and many Internet stocks were sold at just a fraction of their initial price. Venture capital investments, however, continued to favor Internet-specific companies over other industries in the postbubble period. In 2001 and 2002, Internet companies received far less venture capital, 28 and 21 percent, respectively, of the total dollars disbursed. This was a sharp drop from the previous 2 years but still more than the amount received by any other industry area. Companies involved primarily in computer software, communication, and medical and health care also continued to attract venture capital-backed investments during this period (figure 6-25).

The decline in enthusiasm for Internet companies seems to have benefited other technology areas, because their shares of total venture capital disbursements increased during a time when venture capitalists were sharply curbing their activity. A comparison of venture capital disbursements in 1999 and 2000 with those in the 2001 and 2002 shows that medical and health care-related and biotechnology companies attracted much higher percentages in the latter period. Medical and health care-related companies received 11 percent of total investments in 2001 and 2002, nearly triple their share of 4 percent received in 1999 and 2000. Biotechnology companies doubled their share, from 3 to about 6 percent. Other industries attracting larger shares of the smaller pool of investment funds in 2001 and 2002 were software companies, semiconductor and other electronics companies, and industrial and energy companies.

Table 6-7

Capital commitments, by limited partner type: 1990–2002

(Billions of U.S. dollars)

Limited partner type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All types	2.55	1.48	3.39	4.12	7.35	8.42	10.47	15.18	25.29	60.14	93.44	2.81	2.54
Pension funds	1.34	0.63	1.41	2.43	3.36	3.12	5.74	5.77	15.03	26.16	37.47	0.83	1.12
Banks and insurance	0.24	0.08	0.49	0.43	0.70	1.62	0.30	0.91	2.59	9.32	21.77	0.37	0.24
Endowments and foundations	0.32	0.36	0.63	0.44	1.57	1.65	1.18	2.43	1.58	10.34	19.72	0.29	0.25
Individuals and families	0.29	0.18	0.37	0.30	0.87	1.36	0.68	1.82	2.83	5.77	11.03	0.75	0.35
Corporations	0.17	0.06	0.11	0.34	0.67	0.35	1.98	3.64	2.97	8.54	3.46	0.41	0.21
Foreign investors	0.19	0.17	0.38	0.18	0.18	0.32	0.59	0.61	0.29	0.00	0.00	0.15	0.00
Other NEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18
Intermediaries	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18

NEC not elsewhere classified

SOURCE: Thomson Venture Economics, special tabulations, June 2003.

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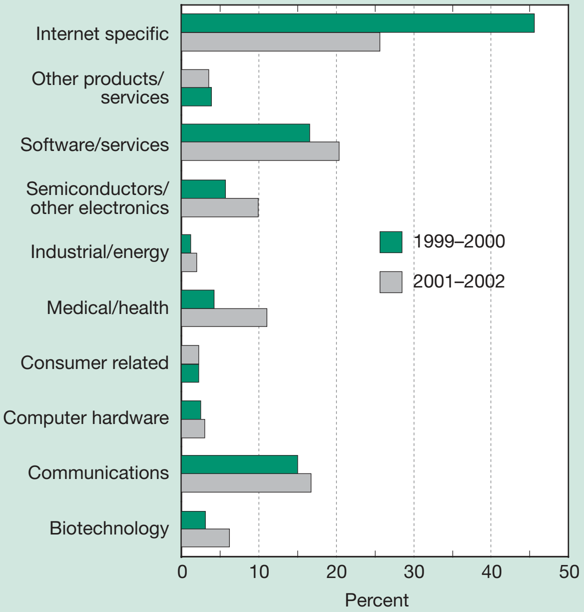
Figure 6-25
U.S. venture capital disbursements, by industry: 1999–2000 and 2001–2002



SOURCE: Thomson Venture Economics, special tabulations, June 2003. See appendix table 6-15.

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Venture Capital Investments by Stage of Financing

The investments made by venture capital firms can be categorized by the stage at which the financing is provided (Venture Economics Information Services 1999):

- **Seed financing** usually involves a small amount of capital provided to an inventor or entrepreneur to prove a concept. It may support product development but is rarely used for marketing.
- **Startup financing** provides funds to companies for product development and initial marketing. This type of financing usually is provided to companies just organized or to those that have been in business just a short time but have not yet sold their product in the marketplace. Generally, such firms have already assembled key management, prepared a business plan, and made market studies.
- **First-stage financing** provides funds to companies that exhausted their initial capital and need funds to initiate commercial manufacturing and sales.
- **Expansion financing** includes working capital for the initial expansion of a company, funds for major growth expansion (involving plant expansion, marketing, or development of an improved product), and financing for a company expecting to go public within 6 months to 1 year.
- **Acquisition financing** provides funds to finance the purchase of another company.
- **Management and leveraged buyout** includes funds to enable operating management to acquire a product line or business from either a public or private company. Often these companies are closely held or family owned.

For this report, the first three types of funds are referred to as *early-stage financing* and the remaining three as *later-stage financing*.

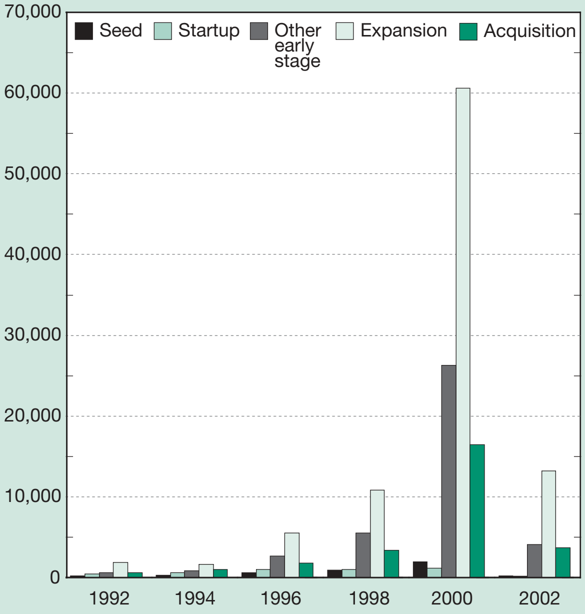
Two patterns stand out in an examination of venture capital disbursements by financing stage: (1) most of the funds' investment dollars are directed to later-stage investments, and (2) during the postbubble period, venture capital funds directed more money to later-stage investments than ever before. (See appendix table 6-16 and sidebar, "U.S. Government Support for Small Technology Businesses.")

Later-stage investments ranged from 60 to 79 percent of total venture capital disbursements, with both the highest and lowest points reached in the 1990s. In 1999 and 2000, later-stage investments made up 72 percent of total disbursements, rising to 77 percent in the postbubble period. Although early-stage, venture-backed investments as a share of total disbursements have gradually declined over time, during the 2001–02 period they fell to their lowest level ever (figure 6-26).

The postbubble trend toward later-stage investing is also evident when analyzing the three early-stage categories. Most of the postbubble venture capital that previously went to early-stage investments shifted to the most mature of the early-stage companies—those companies that had exhausted

Figure 6-26
U.S. venture capital disbursements, by stage of financing: 1992–2002

Millions of U.S. dollars



SOURCE: Thomson Venture Economics, special tabulations, June 2003. See appendix table 6-16.

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U.S. Government Support for Small Technology Businesses

In contrast to profit-driven venture capital, U.S. Government programs support the development of new technologies to better address broader national interests and scientific needs. Two Federal programs are prominent in this effort: (1) The Small Business Innovation Research Program administered by the U.S. Small Business Administration, and (2) the Advanced Technology Program, administered by the U.S. Department of Commerce.

The Small Business Innovation Research Program (SBIR) sprang from the 1982 Small Business Innovation Development Act and was reauthorized in 1992 with an explicit emphasis on commercialization. Each Federal agency with extramural research programs greater than $100 million is required to set aside a fixed percentage of funding (currently 2.5 percent) for SBIR projects. Small businesses submit proposals to each of the agencies describing projects that meet an agency's research needs and have commercial potential.

The Advanced Technology Program (ATP) has funded the development of enabling technologies since 1990. In this program, companies, nonprofit institutions, and universities submit proposals that undergo a peer review process that evaluates the technical and economic potential of the project.

Table 6-8 shows the annual funding for these two programs since 1990. SBIR's set-aside mechanism has led to a gradual expansion of funds available to small technology-oriented firms, as opposed to the highly variable ATP appropriations.

Table 6-8
Federally and privately funded early-stage venture capital
(Millions of U.S. dollars)

Year	Federal SBIR	Federal ATP	Private early-stage venture capital
1990..............	461	46	1,148
1991..............	483	93	826
1992..............	508	48	1,186
1993..............	698	60	2,100
1994..............	718	309	1,581
1995..............	835	414	2,143
1996..............	916	19	2,658
1997..............	1,107	162	3,373
1998..............	1,067	235	4,700
1999..............	1,097	110	10,995
2000..............	1,190	144	20,260
2001..............	1,294	164	764
2002..............	NA	156	1,813

ATP Advanced Technology Program
NA not available
SBIR Small Business Innovation Research

NOTE: Data reflect disbursements funded publicly through Federal SBIR and ATP and privately through U.S. venture capital funds.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Science and Engineering Indicators – 2002*, p. 4-36 through 4-38; and Thomson Venture Economics, special tabulations, June 2003.

Science and Engineering Indicators – 2004

their initial capital and were in need of funds to initiate commercial manufacturing and sales. During a period when venture capital became increasingly scarce, the more high-risk early-stage projects suffered.

Expansion financing has typically been favored by venture capital funds, with this stage alone accounting for more than half of all venture capital disbursements since 1997. In 2000, the amount of venture capital invested to finance company expansions reached 57 percent of total disbursements. This upward trend continued into the postbubble period, with the share rising to 62 percent in 2002. About one-quarter of the $36.3 billion disbursed to finance expansions of existing businesses during 2001 and 2002 went to Internet companies.

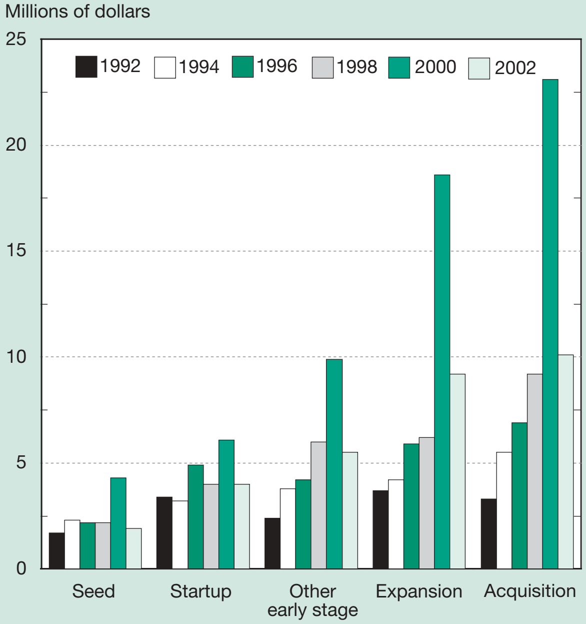
Venture Capital as Seed Money

Contrary to popular perception, only a relatively small amount of dollars invested by venture capital funds ends up as seed money to support research or early product development. Seed-stage financing never accounted for more than 8 percent of all disbursements over the past 23 years and most often represented between 2 and 5 percent of the annual totals. The latest data show that seed financing represented just 1 percent of all venture capital in 2001 and 2002, falling from just 2 percent in 1999 and 2000. Over the past 23 years, the amount invested in a seed-stage financing has averaged about $1.8 million per disbursement. The average peaked at $4.3 million per disbursement in 2000 before falling in 2001 and 2002 (figure 6-27). In 2002, the average seed-stage investment was about $1.9 million.

The same three technologies, Internet, communication, and computer software, attracted the bulk of seed financing during the past 4 years. They were the largest recipients of venture capital seed financing during the 1999 and 2000 bubble years, with Internet companies the preferred investment destination. Internet companies received 58 percent of all disbursements in 1999 and 43 percent in 2000 (appendix table 6-17). In 2001 and 2002, seed investments going to Internet companies fell off considerably but still represented 21 percent of all such investments in 2001 and 7 percent in 2002.

As dot.com panic replaced dot.com mania, other technology areas attracted more attention. Medical and health care-related companies received 10 percent of seed money in 2001 and 20 percent in 2002, up from 4 and 5 percent during the bubble years. The share going to biotechnology companies rose to 5 percent in 2001 and to 15 percent in

Figure 6-27
Value of average investment by venture capital funds, by stage of financing: 1992–2002



SOURCE: Thomson Venture Economics, special tabulations, June 2003. See appendix table 6-16.

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2002. Semiconductor companies received 8 percent in 2001 and 15 percent in 2002, up from 4 percent in 1999.

Over the past 23 years, venture capital investment showed consistent support for technology-oriented businesses, particularly companies and industries that develop and rely on information technologies. And, despite the recent reduction in new money invested in venture capital funds, information technologies continue to attract the largest shares of total U.S. venture capital.

During the late 1990s, venture capitalists increasingly favored later-stage investments over early-stage investments that are more likely to support exploratory R&D and product development. That trend continued in the postbubble years of 2001 and 2002. If this trend continues, U.S. Government programs like the Small Business Innovation Research program and Advanced Technology Program may become more important sources of early-stage funds for new technology-oriented businesses.

Characteristics of Innovative U.S. Firms

The need for better information about innovative activities at U.S. firms, the innovative process, and the factors that affect innovation led NSF to conduct a new survey in 2001 that systematically examined innovative activities in selected U.S. industries. To accomplish this, and to better understand how IT affects innovation, 4,000 firms were surveyed with the following three goals in mind:

- To develop nationally representative profiles of corporate IT innovators and users
- To facilitate analyses of similar national studies conducted by other countries
- To provide policymakers with data to better understand how industry uses and develops IT in the pursuit of innovation

Data collected from this survey were designed to serve both public and private researchers and provide an important resource for NSF, policymakers, and other stakeholders interested in understanding the multidimensionality of IT-based innovation within U.S. companies. These data are limited in scope and depth but nevertheless provide useful insight into the process and characteristics of IT-based industrial innovation. (See sidebar, "Description of U.S. IT Innovation Survey Sample and Response.")

Why Study IT-Based Innovation?

In the late 1990s, IT was recognized by the U.S. Department of Commerce as an area of growing importance within the U.S. economy (DOC 1998 and DOC/ESA 1999). This growth was evident by the impact of IT on the labor market in the form of rising demand for IT workers and the shortage of trained IT professionals (DOC/ESA 1999, DOC/OTP 1998, and Meares and Sargent 1999). During this time, IT and IT innovation was recognized as a major contributor to the service sector. It was reported that about 80 percent of IT investment was directed to the service sector in both the United States and United Kingdom (Evangelista, Sirilli, and Smith 1998).

IT-based innovation was viewed as both leading to new products and services and revitalizing the way most traditional services were produced and delivered (Evangelista, Sirilli, and Smith 1998). The introduction of IT and IT-based innovations reduced costs in production- and scale-intensive sectors, whereas specialized technology suppliers and science-based sectors used IT to focus on R&D and software development (Evangelista, Sirilli, and Smith 1998). IT was especially important to supplier-dominated industries that relied on technologies developed by other sectors. Furthermore, in a review of U.S. policy on investment in innovation, Branscomb and Keller (1998) found that assumptions about the way companies innovate have not kept pace with structural changes in the high-technology sector of the economy, particularly as they relate to:

- Sources of technology and funding for innovation
- Challenges to competitiveness in the global marketplace
- The nature of relationships between companies, government, and the academic community
- Decentralization of technology management responsibilities and corporate decisionmaking

Description of U.S. IT Innovation Survey Sample and Response

In 1999, NSF contracted with the PricewaterhouseCoopers Survey Research Center (now IBM Business Consulting Services) to develop and conduct the Information Technology Innovation Survey. The survey was designed to systematically examine business characteristics and activities in U.S. industry related to IT-based innovation. The survey went to approximately 4,000 for-profit, single-location firms (or to the corporate headquarters for multilocation businesses) with 25 or more employees and annual sales of at least $2.5 million.

The target population was limited to firms associated with developing information technologies (IT strata) and industries in which IT-based innovation may have had an impact (non-IT strata). The four non-IT strata included select companies from the remaining manufacturing standard industrial classifications (SICs); the transportation and public utilities sector; the service sector; and the finance, insurance, and real estate sectors. The IT sector industries were grouped into three IT strata composed of industries specializing in computer equipment, electronic and electrical equipment, and measuring, analyzing, and controlling instruments; communication (telephone, radio, television, etc.); and computer-related business services from the service sector. None of the four-digit SIC codes within the finance, insurance, and real estate sector were identified as part of the IT strata.

Based on an analysis of existing sources from which to draw the sample, Dun & Bradstreet's "Marketplace" database software was selected and licensed as the source for the sample frame. The database is a comprehensive listing of more than 10 million business establishments covering all industries in the United States.

A total of 2,005 companies responded to the survey, representing an estimated population of 72,406 companies. Of the 2,005 respondents, 66 percent responded by telephone (computer-assisted telephone interview), 22 percent by Web, and 12 percent by paper.

After adjusting the sample for companies determined to be out-of-frame and out-of-scope, the final adjusted response rate was 57.2 percent. The highest response rate (65.4 percent) was recorded for the non-IT services stratum, and the lowest response rate (50.3 percent) was for the non-IT manufacturing stratum. Response among companies in the IT and non-IT sectors was the same (57 percent). Item nonresponse was minimal.

- Managing risk and determining returns on investment in education, research and development, and organizational change

New patterns in private-sector innovation are assumed to reach across companies in the form of increased partnerships, alliances, and other forms of collaboration, although quantitative data are not available to support this assumption (Branscomb and Keller 1998).

Survey Results

For the purposes of the NSF study, innovation was defined as the development of technologically new or significantly improved products or processes. Respondents were instructed to consider innovation IT-based if IT was a significant or critical component in the development of new products or processes. Changes to existing products that were purely aesthetic, involved only minor modifications, or were implemented to accommodate Y2K issues were not considered IT-based innovation.

The survey found that nearly half (48 percent) of responding firms developed an IT-based innovation within the past year or expected to develop one within 12 months. This 48 percent is an estimated national average rate of IT-based innovation for the collection of industries surveyed. Not surprisingly, certain industries reported above-average levels of innovation. For example, IT companies reported higher levels of innovation (72 percent) than non-IT companies (44 percent), and IT computer-related services (84 percent) were the most innovative of the three IT sectors surveyed. The lowest rate of innovation was reported in the non-IT manufacturing sector (figure 6-28 and table 6-9).

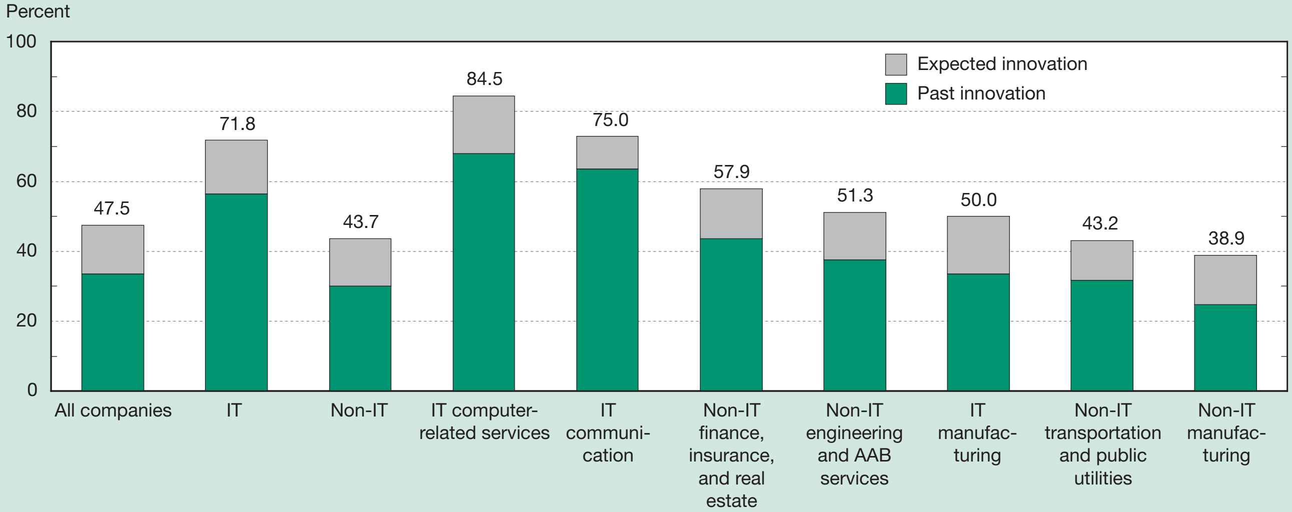
Process innovation was more prevalent and may be more important for innovative firms than product innovation (appendix tables 6-18 through 6-21). When innovative firms were asked to identify the type of innovation (product or process) developed during the past year that contributed most to company revenue, process innovations outnumbered product innovations by almost 60 percent (figure 6-29). The number of firms that said they expected to have an IT-based process innovation within 12 months outnumbered firms expecting a product innovation by more than 2 to 1 (appendix table 6-21). This survey defined *product innovation* as the development of improved goods or services in which IT was a significant or critical component, and *process innovation* as the development of an improved operation, or function associated with manufacturing, production, or business services in which IT was a significant or critical component.

The survey identified several characteristics of innovative U.S. companies. Larger companies were more likely to report higher rates of innovation than smaller companies. Using annual revenue as a proxy for size, 63 percent of companies with more than $50 million in sales revenue reported they had developed an IT-based innovation in the past 12 months or expected to do so within the next 12 months, compared with 43 percent of the smallest firms, those with annual company revenues between $2.5 million and $4.9 million.

Innovative firms did not appear to be statistically more likely to export their products than noninnovtive firms. Sixteen percent of companies that introduced a new IT-based innovation reported serving foreign customers compared with 14 percent of noninnovative firms.

Figure 6-28

Companies reporting IT-based innovation in past 12 months or expected innovation in next 12 months, by sector: 2001



IT information technology
AAB accounting, auditing, and bookkeeping

SOURCE: National Science Foundation, Division of Science Resources Statistics, Information Technology Information Survey, 2001. See appendix tables 6-18 and 6-19.

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Table 6-9

Companies reporting IT-based innovation in past 12 months or expected innovation in next 12 months, by industry and revenue size: 2001

(Percent)

Characteristic of innovator[a]	Total	Past	Expected
All industries	48	34	14
IT	72	57	15
Manufacturing	50	33	17
Communications	75	63	13
Computer-related services	84	67	18
Non-IT	44	30	14
Manufacturing	39	25	14
Transportation and public utilities	44	32	12
Finance, insurance, and real estate	58	44	14
Engineering and AAB services	52	38	14
Revenue size (millions of dollars)			
2.5–4.9	43	29	14
5–9.9	46	33	13
10–24.9	48	34	14
25–50	58	35	23
More than 50	63	56	7

AAB accounting, auditing, and bookkeeping
IT information technology

[a] To be classified as innovator, the company had to have developed a product or process in the past 12 months or believed it would develop a product or process in the next 12 months as a result of IT-based innovation. The survey was conducted during the period July 2001 to April 2002.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Information Technology Information Survey, 2001. See appendix tables 6-18 and 6-19.

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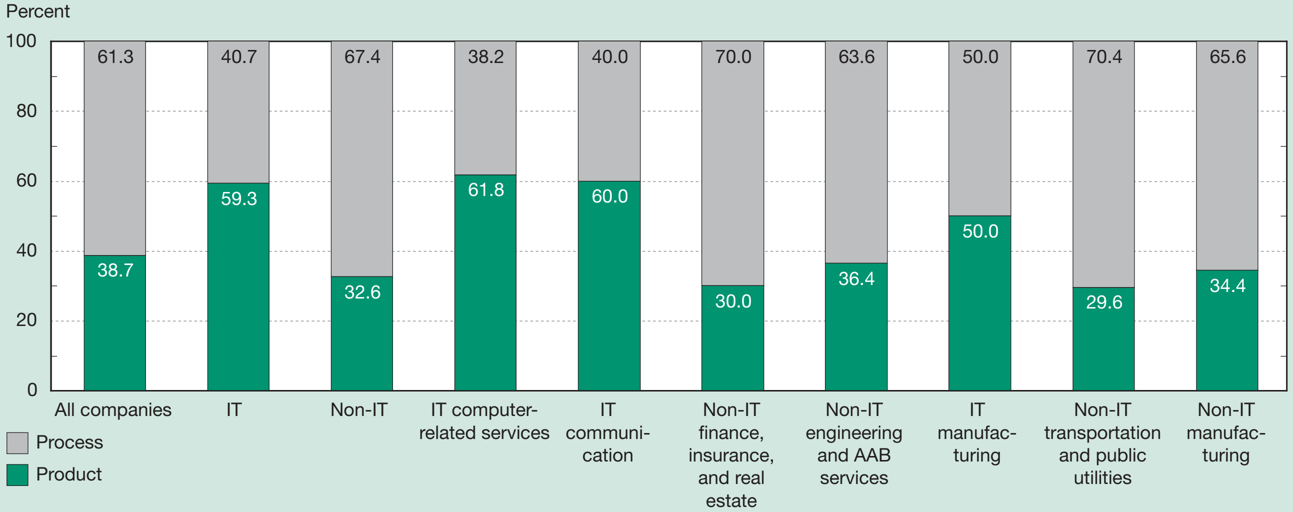
Figure 6-29
Type of innovation contributing most to company revenue, by sector: 2001



IT information technology
AAB accounting, auditing, and bookkeeping

SOURCE: National Science Foundation, Division of Science Resources Statistics, Information Technology Information Survey, 2001. See appendix table 6-20.

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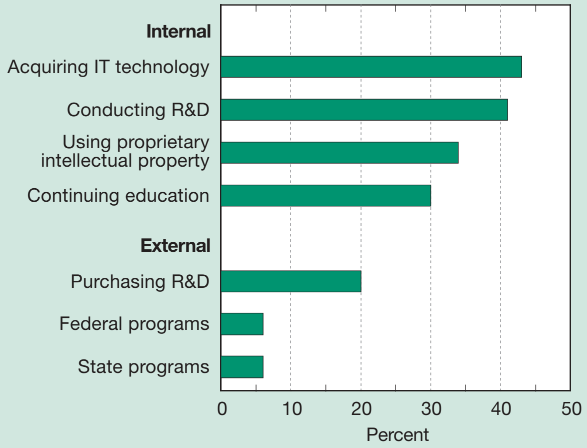
Innovative companies were asked about various internal and external factors that contributed to their IT-based innovation. Among the internal factors cited, respondents considered acquiring IT and conducting R&D to be the most important. Forty-three percent of innovative firms said acquiring IT made a large contribution to their IT-based innovation, and 41 percent said the same about conducting in-house R&D (figure 6-30).

Figure 6-30
Internal and external factors contributing to IT-based innovation: 2001



IT information technology

NOTE: Data represent those who said factor was very important.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Information Technology Information Survey, 2001.

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With respect to the other internal factors posed to respondents, 34 percent of innovators said using proprietary intellectual property made a large contribution to innovation, and 30 percent cited continuing education. Sector differences on this question are worth noting. Conducting R&D was cited as an important contributor to innovation by more IT companies (58 percent) than non-IT companies (37 percent), whereas acquiring IT technology meant more to non-IT companies (44 percent) than to IT companies (39 percent). This suggests that purchasing technology during the innovation process may be an effective substitute for developing technology through internal R&D. These results demonstrate how technology that is developed in one company or industry and acquired by others plays an important role in the acquiring company's innovation process.

External factors appear to have a lesser impact on innovative companies than internal factors. Among the seven factors posed to respondents, purchasing external R&D was the most highly valued, and it garnered this response from only 20 percent of respondents. Federal and state programs were the least valued; only 6 percent of innovative firms identified these programs as having made a large contribution to the firm's IT-based innovation.

The IT innovation survey answered several other questions as well:

- **What did innovators say provided incentive for IT-based innovation?** The availability of skilled IT personnel and favorable timeframes for realizing a return on investment were each considered an incentive by 45 percent of firms. R&D-associated costs were seen neither as an incentive nor a deterrent; the same was true for current tax policy, access to capital, and the existence of environmental regulations.

- **What did innovators see as strategically important for their firm's growth? Were their views different from those held by noninnovators?** Innovators viewed being the first to market as strategically very important, were more focused on expanding into new geographic regions, and placed a higher importance on conducting R&D than noninnovators. Innovators also viewed forming alliances, partnerships, or joint ventures as a more important business strategy than noninnovators. Innovators were more concerned about retaining skilled IT personnel (47 percent felt it was very important versus 24 percent of noninnovators) and viewed it as strategically very important for their business. Somewhat surprisingly, venture capital was not an overriding concern for innovators and noninnovators. Seventeen percent of innovators saw it as very important compared with 12 percent of noninnovators.
- **How important is IT hardware and software relative to other elements for conducting business?** Almost 60 percent of responding firms viewed IT hardware and software as very important for conducting business. Innovators weighted it even more, with nearly 74 percent reporting it as very important to their business.
- **How did firms view the utility of IT goods and services?** Firms saw IT goods and services as very important for reducing costs (54 percent of all respondents gave this answer, as did 67 percent of innovators and 43 percent of noninnovators), increasing productivity (64 percent overall, 77 percent of innovators, and 52 percent of noninnovators), and facilitating communication (61 percent overall, 75 percent of innovators, and 49 percent of noninnovators). Firms did not view IT goods and services as very important for attracting investment.
- **How important is R&D to the innovation process?** Forty-one percent of innovators said in-house R&D made a large contribution to IT-based innovation, 31 percent said that conducting R&D was a very important part of a growth strategy, and 20 percent said outsourced R&D made a large contribution toward IT-based innovation.

The development of innovation theory and the collection of data go hand in hand. This latest data collection effort by NSF drew on myriad experiences of related innovation surveys conducted in Europe, Asia, and Latin America, but it broke new ground by focusing exclusively on IT-based innovation. By designing the data collection process for a narrower set of innovations and industries, this survey strived to address practitioner concerns about the usefulness of national innovation data while trying to understand the innovation process in specific industries. The focus on IT-based innovation sought to improve the data currently available and to investigate the innovation process in this critical technology area.

Conclusion

Despite signs of a slowing economy, the United States continues to rank among the leaders in all major technology areas. Advances in U.S. aerospace, computer, and telecommunication industries continue to influence new technology development and dominate technical exchanges between the United States and its trading partners. New data on patenting trends in the United States bears this out and may suggest a level of optimism by U.S. and foreign inventors in the U.S. economy.

The United States also continues to be a leading provider of knowledge-intensive services, but it may face greater competition in the near future as European countries devote more resources to service-sector R&D. For now, however, exports of U.S. technological know-how sold as intellectual property continue to exceed U.S. imports of technological know-how.

Though strong, U.S. high-technology industries have struggled in the shrinking economy and in the aftermath of the September 11 terrorist attacks. Declining investment in IT has clearly affected the bottom line in U.S. firms producing computer hardware and software. Firms involved in all aspects of communication, along with those in the U.S. aerospace industry, may be facing the greatest challenges. Airlines have sharply cut back orders due to declines in travel and tourism, and they face tougher competition in their struggle to retain market share while addressing the challenges raised by the events of September 11 and the still evolving societal and economic reactions to them. The event itself affected the nation in myriad ways, but it set an already struggling U.S. aerospace industry on its heels, and the industry continues to lose world market share.

Asia's status as both a consumer and developer of high-technology products has been enhanced by development in many Asian economies, particularly Taiwan, South Korea, and China. Several smaller European countries also exhibit growing capacities to develop new technologies and to compete in global markets.

The United States continues to be a leading developer and supplier of high-technology both at home and abroad. This success has likely been influenced by a combination of factors: the nation's long commitment to investments in S&T; the scale effects derived from serving a large, demanding domestic market; and the U.S. market's willingness to adopt new technologies. These same market dynamics already show signs of benefitting Asia and a more unified Europe and will likely enhance the value of their investments in S&T.

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Chapter 7

Science and Technology: Public Attitudes and Understanding

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Highlights

- **Although Americans express strong support for science and technology (S&T), they are not very well informed about these subjects.** Many in the scientific community are concerned that lack of knowledge about S&T may adversely affect the level of government support for research, the number of young people choosing S&T careers, and the public's resistance to miracle cures, get-rich-quick schemes, and other scams.

Information Sources

- **Most adults pick up information about S&T primarily from watching television; the print media are a distant second.** This is true in both the United States and Europe. Several types of television shows play a role in communicating science to the public, including educational and nonfiction programs, newscasts and newsmagazines, and even entertainment programs. However, television (and other media) can be faulted for miscommunicating science to the public by sometimes failing to distinguish between fantasy and reality and by failing to cite scientific evidence when it is needed.
- **The Internet is having a major impact on how the public gets information about S&T.** According to the 2001 National Science Foundation (NSF) survey, the Internet is the preferred source when people are seeking information about specific scientific issues, an indication that encyclopedias and other reference tools have lost a substantial number of customers to the Internet.
- **Books about science influence popular culture and public debate on policy issues.** Beginning in the late 1970s, science-related books began to win more Pulitzer Prizes and appear more often on bestseller lists. Books by the late Carl Sagan achieved publishing milestones that indicate a growing interest in science among the book-reading public.
- **S&T museums are much more popular in the United States than in Europe.** Americans were nearly three times as likely as Europeans to have visited an S&T museum within the past year.

Public Interest in S&T

- **Evidence about the public's interest in S&T is mixed.** Surveys conducted by the Pew Research Center for the People and the Press found that S&T ranked only 9th of 13 categories of news followed most closely by the public in 2002. Yet science/health and technology ranked second and fourth, respectively, as categories of news sought online. The data also indicate that interest in S&T news seems to have declined between 1996 and 2002, along with interest in most subjects. The popularity of science museums and books suggests that people are interested in science even though they may not be following science-related news.
- **Very few Americans admit to not being interested in S&T issues.** Only about 10 percent of surveyed Americans said they were not interested in news about scientific discoveries or new inventions and technologies. In Europe, however, half of surveyed residents said they were not interested in S&T.

Public Knowledge About S&T

- **Neither Americans nor Europeans got high marks in a 2001 quiz designed to measure their knowledge of science.** Out of 13 questions, Americans answered an average of 8.2 correctly, Europeans 7.8.
- **Science knowledge in the United States and Europe is not improving.** Respondents' ability to answer most questions about science has remained essentially unchanged since the 1990s, with one exception: more people now know that antibiotics do not kill viruses. This may be attributable to media coverage of drug-resistant bacteria, an important public health issue.
- **More Americans now agree with the theory of evolution.** The 2001 NSF survey marked the first time that more than half (53 percent) of Americans answered "true" in response to the statement "human beings, as we know them today, developed from earlier species of animals." (In Europe, 69 percent responded "true.") Whether and how the theory of evolution is taught in public schools remains one of the most contentious issues in U.S. science education.
- **Most Americans (two-thirds in the 2001 NSF survey) do not clearly understand the scientific process.** Knowing how ideas are investigated and analyzed—a sure sign of scientific literacy—is important. Critical thinking skills are invaluable not only in science but also in making wise and well-informed choices as citizens and consumers.
- **Studies seem to indicate that not many Americans are "technologically literate."** In addition, the public's understanding of technology lags behind its professed interest in the subject.
- **Belief in various forms of pseudoscience is common in both the United States and Europe.** For example, 60 percent of surveyed Americans said they believe in extrasensory perception, and 41 percent thought that astrology is at least somewhat scientific. More than half of surveyed Europeans said they believe in astrology. Because society is heavily dependent on S&T, scientists are concerned about the persistence of beliefs that run contrary to scientific evidence.

- **A recent poll of scientists found that 42 percent engaged in no public outreach.** Asked why, 76 percent said they did not have time, 28 percent did not want to, and 17 percent did not care. Only 12 percent of the surveyed scientists said they were engaged in political outreach, and 20 percent were in contact with the media.

Public Attitudes About Science-Related Issues

- **Americans generally have highly favorable attitudes regarding S&T.** Attitudes are more positive in the United States than in Europe. For example, in 2001, 72 percent of Americans, compared with 50 percent of Europeans, agreed that the benefits of scientific research outweigh any harmful results.
- **All indicators point to widespread support for government funding of basic research.** In 2001, 81 percent of NSF survey respondents agreed with the following statement: "Even if it brings no immediate benefits, scientific research that advances the frontiers of knowledge is necessary and should be supported by the Federal Government." In Europe, 75 percent of those surveyed agreed with the statement.
- **Optimism about biotechnology actually increased in Europe between 1999 and 2002.** A similar trend occurred in the United States during the same period. However, antibiotechnology sentiments remain more common in Europe than in the United States.
- **Technologies based on genetic engineering are controversial.** Americans overwhelmingly oppose human cloning but are more divided on the subject of medical research that uses stem cells from human embryos. Support for the latter has fluctuated, but in 2003, 47 percent of the public expressed support for stem cell research, and 44 percent were opposed.
- **Americans continue to express confidence in the science community.** In addition, the events of September 11, 2001, seemed to affect the ranking of institutions based on public confidence, giving rise to a surge in ratings for the military and the executive branch of the Federal Government.
- **The public seems to recognize that S&T play a role in combating terrorism.** In one survey, about 90 percent of respondents said that scientific research is either extremely or very important to prepare for and respond to threats of bioterrorism, and more than 80 percent strongly or somewhat supported increased funding for such research.
- **Attitudes toward environmental protection have been shifting in recent years, according to a Gallup survey.** In 2003, 47 percent of those surveyed chose the statement "protection of the environment should be given priority, even at the risk of curbing economic growth," compared with 42 percent who chose its alternative, "economic growth should be given priority, even if the environment suffers to some exent." However, the percentage choosing the former has been declining since 2000, and the percentage choosing the latter has been increasing.

Introduction

Chapter Overview

The vast majority of Americans recognize and appreciate the benefits of science and technology (S&T). They are aware of the role new discoveries play in ensuring their health and safety and the health of the economy. They have welcomed a wide variety of inventions—automobiles, household appliances, and motion pictures, to name just a few—that have improved their quality of life and standard of living. More recently, Americans have enthusiastically embraced major advancements in communication technologies, including the Internet, cellular telephones, and DVD players.

The public is also highly supportive of the government's role in fostering and funding scientific research. According to a survey conducted at the end of the millennium, Americans believe that advancements in S&T were the nation's and the government's greatest achievements during the 20th century (Pew Research Center for the People and the Press 1999).

Although Americans are highly supportive of S&T, their knowledge is limited. Many people do not seem to have a firm understanding of basic scientific facts and concepts. Experts in science communication encounter widespread misunderstanding of how science works. Moreover, surveys conducted by the National Science Foundation (NSF)[1] and other organizations show minimal gains over time in the public's knowledge of science and the scientific method and suggest that belief in astrology and other forms of pseudoscience is widespread and growing.

According to a recent report (NIST 2002), many in the scientific community are concerned that the public's lack of knowledge about S&T may result in:

- Less government support for research
- Fewer young people choosing S&T careers
- Greater public susceptibility to miracle cures, get-rich-quick schemes, and other scams

Chapter Organization

This chapter examines aspects of the public's attitudes toward and understanding of S&T. In addition to data collected in surveys sponsored by NSF, the chapter contains extensive information from studies and surveys undertaken by other organizations that track trends in media consumption and changes in public opinion on policy issues related to S&T. (See sidebar "Data Sources.") One of these sources is the most recent Eurobarometer on "Europeans, Science and Technology" (European Commission 2001), the first comprehensive survey of residents in all European Union member states in nearly a decade.

The chapter is in three parts. The first part focuses on S&T-related information and interest. It begins with a section on sources of news and information, including a detailed look at the role of the Internet. It then examines several measures of public interest in S&T. (Level of interest indicates both the visibility of the science and engineering community's work and the relative importance accorded S&T by society.) The first part also briefly discusses the public's perception of how well informed it is about science-related issues.

The second part of the chapter covers knowledge of S&T. It touches on the importance of scientific literacy; indicators of the public's familiarity with scientific terms and concepts, the scientific method, and technology; and belief in pseudoscience.

The third part examines public attitudes about S&T. It presents data on public opinion about Federal funding of scientific research and public confidence in the science community. It also includes information on how the public perceives the benefits and harms of scientific research and genetic engineering.

Information Sources, Interest, and Perceived Knowledge

People get news and information about S&T from a variety of sources. However, in both the United States and Europe, most adults find out about the latest S&T developments from watching television. The print media rank a distant second. The Internet, although not the main source of news for most people, has become the main place to get information about specific S&T subjects.

Although most Americans claim to be at least moderately interested in S&T, few science-related news stories attract much public interest. In addition, few people feel well informed about new scientific discoveries and the use of new inventions and technologies.

Sources of News and Information About S&T

The number of people who watch the news on television or read a newspaper has been declining for more than a decade.[2] That does not bode well for news about S&T, which must compete with a host of other topics for the attention of the American public.

Although the percentage of Americans who regularly watch a nightly network news program has declined steadily since the late 1980s,[3] television remains the leading source of news in most households. In the 2001 NSF survey, 53 percent of respondents named television as their leading source of news about current events in general, followed by newspapers (29 percent). Television was also the leading source of news

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[1] The most recent NSF survey was conducted in 2001.

[2] Although news consumption spiked after the events of September 11, 2001, the number of people who keep up with current events has generally been declining. Americans, especially young people, are increasingly likely to report that they did not watch or listen to the news or read a newspaper the previous day. Between 1994 and 2002, the proportion of people in this category doubled from 10 to 20 percent (Pew Research Center for the People and the Press 2002a).

[3] The proportion of Americans who said they regularly watched a nightly network news program declined from 71 percent in 1987 to 50 percent in 2000. The steady decline appears to have leveled off: in the most recent survey by the Pew Research Center for the People and the Press (2002a), 52 percent of respondents said they watched nightly network news.

Data Sources

Data from the following surveys are included in this chapter.

Sponsoring organization	Title/year*	Information used in the chapter
National Science Foundation	Survey of Public Attitudes Toward and Understanding of Science and Technology (S&T) (2001)	Various knowledge and attitude items, including public support for basic research, belief in pseudoscience, and interest in S&T
European Commission	Eurobarometer 55.2 Europeans, Science and Technology (2001)	Various knowledge and attitude items for European public, including support for basic research, trust in scientists, and views on mad cow disease
European Commission	Eurobarometer 58.0 Europeans and Biotechnology (2002)	European attitudes toward biotechnology
Bayer Corporation	Bayer Facts of Science Education (2003)	Public awareness of the relationship between S&T and national security
The Gallup Organization	Various ongoing surveys (2003)	Public attitudes toward the environment, cloning, space exploration, and biotechnology, and belief in pseudoscience
The Gallup Organization	What Americans Think About Technology (2001)†	Public attitudes toward and understanding of technology
Harris Interactive	The Harris Poll (2002)	Prestige of various occupations
Pew Research Center for the People and the Press	Various ongoing surveys (2002)	Media consumption and public attitudes toward technology
Research!America	Various ongoing surveys (2003)	Public attitudes toward funding health and scientific research
UCLA Center for Communication Policy	Surveying the Digital Future (2002)	Public attitudes toward and use of the Internet
University of Chicago	General Social Survey (2002)	Public confidence in various institutions and government funding of programs
Virginia Commonwealth University Center for Public Policy	VCU Life Sciences Survey (2003)	Public attitudes toward scientific progress and moral values, stem cell research, and genetic testing

*For ongoing surveys, most recent year is shown.

†Conducted for the International Technology Education Association.

about S&T (44 percent), followed by newspapers and magazines (each 16 percent).[4] Despite the growing popularity of the Internet, and the steady stream of technological advances that support the convergence of computer and television capabilities (Markoff 2002), relatively few respondents named the Internet as their leading source of general news (7 percent) or S&T news (9 percent). However, when respondents were asked where they would go to get additional information about a specific scientific topic, such as biotechnology or global warming, nearly half named the Internet (figure 7-1 and appendix tables 7-1, 7-2, and 7-3).

Television is also the European public's main source of news about S&T.[5] In the 2001 Eurobarometer survey, 60 percent of respondents ranked television as either their first or second most important source of information on scientific developments, followed by the written press (37 percent), radio (27 percent), school or university (22 percent), scientific journals (20 percent), and the Internet (17 percent) (figure 7-2). In general, there was little variation in these preferences across countries (table 7-1).

The following sections take a more detailed look at the various sources of news and information about S&T in the United States.

Television

Information about science is communicated to the U.S. public through several types of television programs. Educational and nonfiction shows promote science and aim to be both informative and entertaining. News programs, including national and local morning and nightly newscasts and newsmagazines, devote segments to science-related subjects and issues. In addition, entertainment programs occasionally include information about science.

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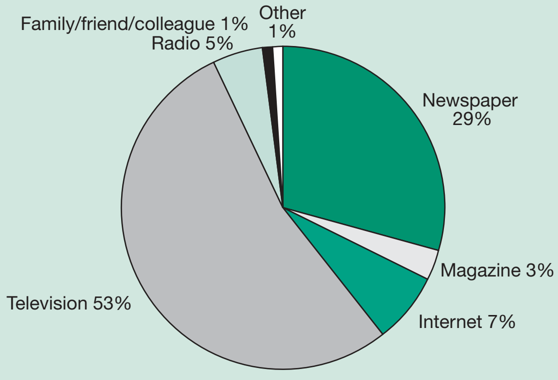
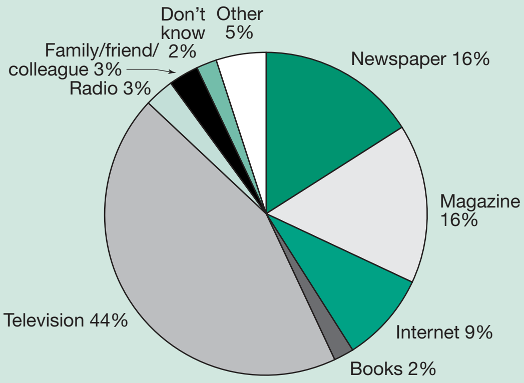
[4] Only 5 percent of respondents named radio as their primary source of general news. Although only 3 percent said radio was their primary source of science and technology (S&T) news, National Public Radio probably has the largest science staff (about 20 editors and reporters) of any national news organization (Girshman 2002).

[5] Data for the United States and Europe are not directly comparable. U.S. respondents were asked to name their primary source of information; Europeans were asked to rank six sources, and their first and second choices were added together.

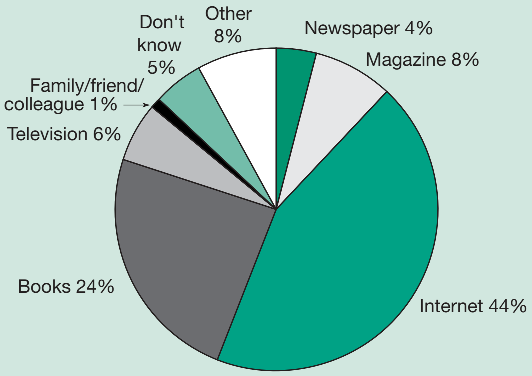
Figure 7-1
Sources of information in United States: 2001



Current news events



Science and technology



Specific scientific issue

NOTES: Categories with less than 0.5% response are not shown. Percents may not sum to 100 because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology, 2001. See appendix tables 7-1, 7-2, and 7-3.

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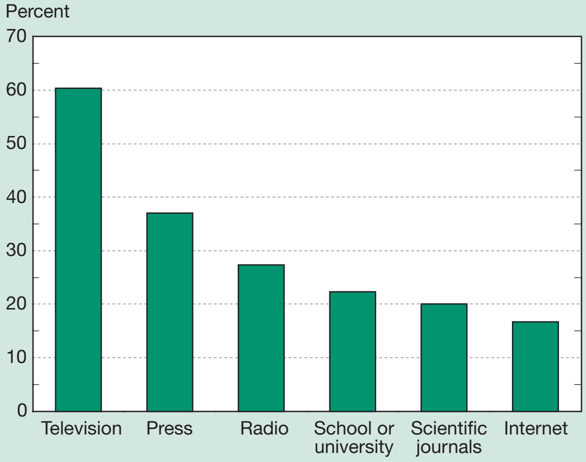
Figure 7-2
Leading sources of information on scientific developments in Europe: 2001



NOTE: Respondents were asked to rank six sources of scientific news, with 1 being most important and 6 being least important. First and second choices were then added together.

SOURCE: European Commission, Eurobarometer 55.2 survey and standard report, *Europeans, Science and Technology,* December 2001.

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A broad range of science-content programs are available on U.S. television, including Public Broadcasting Service (PBS) series (such as *Nova*)[6] and programs aimed at children (such as *Bill Nye the Science Guy*). Most U.S. households now have cable or satellite television and thus have access to the Discovery Channel and a growing array of options made possible by advances in cable and satellite technology. These include an increasing number of channels devoted to S&T and health (e.g., Discovery Health, the National Geographic Channel, and the History Channel)[7] and niche market channels [e.g., the Research Channel, the University Channel, and NASA TV (Folkenflik 2003)].

Nova[8] and other science programs have become highly dependent on visual images. Advances in photographic technology and computer graphics, such as microscopic visuals and computer-generated imagery (CGI), have made it possible to create shows on subjects like genomics, cosmology, and string theory. In addition, CGI can create realistic images of worlds that no longer exist (e.g., the shows "Walking with Dinosaurs" and "Walking with Beasts").

Most programs and documentaries on PBS and cable and satellite channels are highly regarded. According to the 2001 NSF survey, 8 percent of Americans watch *Nova* regularly

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[6] According to the executive producer of *Nova*, "science lends itself so well to a mystery story. It always starts with a question… Another element of a science story is usually a star or a cast of characters—some researcher or a group" (Apsell 2002).

[7] In one survey, 37 percent of respondents said they regularly watched documentaries on cable channels. More men than women said they watched these shows (Pew Research Center for the People and the Press 2000a).

[8] Hollywood has occasionally taken its cues from *Nova*. For example, the idea for the 1999 movie *Twister,* which drew notice for its special effects, actually came from the *Nova* episode "Tornado" (Apsell 2002).

Table 7-1
Leading sources of information on scientific developments in Europe, by country: 2001
(Percent)

Country	Television	Press	Radio	School or university	Scientific journals	Internet
All	60	37	27	22	20	17
Belgium	64	37	30	25	21	18
Denmark	61	39	23	28	17	16
Germany	68	44	26	14	15	14
Greece	62	30	33	29	13	10
Spain	53	26	34	25	17	14
France	65	35	34	17	21	10
Ireland	61	39	40	21	14	20
Italy	49	28	16	34	33	24
Luxembourg	42	30	24	19	14	14
Netherlands	59	49	36	27	21	23
Austria	65	41	41	14	16	16
Portugal	59	23	28	19	8	14
Finland	59	50	21	27	22	18
Sweden	66	46	25	23	21	14
Great Britain	60	42	26	23	19	23

NOTE: Respondents were asked to rank six sources of scientific news, with 1 being most important and 6 being least important. First and second choices were then added together.

SOURCE: European Commission, Eurobarometer 55.2 survey and standard report, *Europeans, Science and Technology,* December 2001.

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or most of the time; another 29 percent watch it occasionally.[9] However, other types of programming, such as evening and morning newscasts and newsmagazines like *60 Minutes*, *20/20*, and *Dateline*, reach far more people. Therefore, most television viewers are exposed to information about S&T in news shows that occasionally cover these subjects.[10]

Although television newsmagazines can be a leading source of news about science for the public, the regular audience for these shows has been declining in the past few years (37, 31, and 24 percent in 1998, 2000, and 2002, respectively, among all adults). Most of this audience erosion occurred among women (Pew Research Center for the People and the Press 2002a).[11]

Local newscasts contain a relatively large number of segments about health and medicine. In addition, more time is spent on the weather than any other story in a local newscast. According to the National Institute of Standards and Technology (NIST 2002), “TV weathercasters are often the most visible representatives of science in U.S. households.” They have educated the public about jet streams, fronts, barometric pressure, and environmental issues such as global climate change and have even involved schools in collecting the data displayed.

Television entertainment programs occasionally dispense information about science to the public.[12] Because such shows attract relatively large audiences, many people may be educated or become aware of science and science-related issues by watching them. However, television can also distort or mischaracterize science and thus contribute to scientific illiteracy (Nisbet et al. 2002). People whose job it is to communicate science information to the public are concerned that the drive for higher ratings is leading television networks to devote more air time to “monsters of the deep, alien abductions, angels, [and] ghosts, all of which pass for science in…the television industry today” (Apsell 2002).[13] Such shows even appear on educational networks, including

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[9] According to one survey, PBS viewership has remained stable (Pew Research Center for the People and the Press 2000a).

[10] For example, in February 2003, *60 Minutes* had a segment on the India Institute of Technology, which trains large numbers of engineers who have become the driving force of innovation in the United States. The long-running series *Sunday Morning* almost always contains at least one segment aimed at fostering public appreciation for S&T; for example, in April 2003, the show included a segment called “Celebrating Einstein’s Genius.”

[11] An assistant managing editor of National Public Radio recently explained that although the network morning shows do have segments on science, physics is not part of the portfolio “because it’s the women who are home getting the kids ready and who have the TV on in the kitchen” (Girshman 2002).

[12] For example, scientists and kids conducting science experiments appear regularly as featured guests on late night talk shows. A lead character on the long-running comedy *Friends* is a paleontologist who is passionate about his work. The dramatic series *The West Wing* has tackled science-related subjects as diverse as the importance of governmental support of basic research, the meaning of the peer review process, and the difference between a physicist and a psychic.

[13] A recent example of this type of program is “Confirmation: The Hard Evidence of Aliens Among Us?,” which, according to the chairman of a university physics department, made it more difficult for viewers to distinguish “charlatans from honest researchers” (Krauss 1999). Other examples include psychics and mediums who either have their own shows or make frequent appearances on talk shows; newscast segments, coinciding with release of the movie *Signs*, devoted to the “mystery” of crop circles (which were exposed as a hoax in 1992); and the special “Conspiracy Theory: Did We Land on the Moon?, ” which drew large numbers of viewers (Oberg 2003). Some scientists view such programs as harmful because “a misinformed public…is as worrisome as an uninformed public” (Chism 2002).

Discovery, The Learning Channel, and The History Channel (Chism 2002).

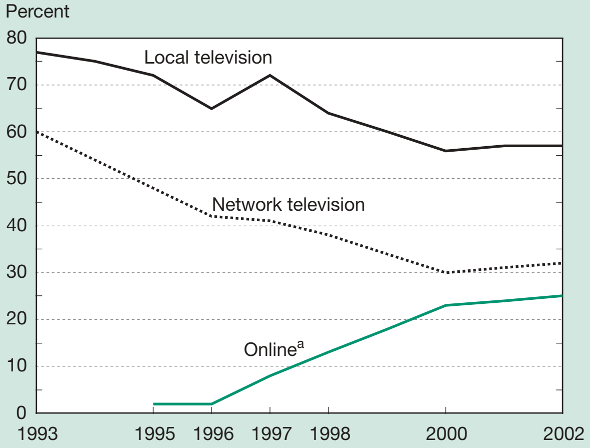
The Internet

Although the Internet has not overtaken television and newspapers as a primary source of news (including S&T news), the results of NSF and other surveys indicate that Internet access is affecting where Americans get news and is an even bigger factor in their acquisition of information about specific scientific issues.

Trends in the Internet as a News Source. According to the Pew Research Center for the People and the Press, the Internet displaced network television in some U.S. households during the late 1990s (figure 7-3). Part of the time Americans used to spend watching television network newscasts is being used instead to browse news-oriented websites. According to the Pew surveys, the percentage of Americans going online for news at least 3 days per week grew from 2 to 23 percent between 1996 and 2000. Even though the number of people connected to the Internet continued to increase between 2000 and 2002, the number relying on the Internet as a news source did not. This finding holds true even among college graduates, who tend to be far more Internet savvy than those with less education.

Characteristics of Internet News Users. The demographic profile of Internet news users has remained virtually unchanged: they tend to be younger, male, more affluent, and better educated. For example, in 2002, Pew survey respondents going online for news at least once a week included 43 percent of those younger than 50 (nearly double the percentage of those 50 and older), 41 percent of men (compared with 29 percent of women), and 57 percent of college graduates (compared with 26 percent of high school graduates).

Figure 7-3
Use of broadcast versus online news: 1993–2001



[a]Online news is obtained at least 3 days a week.

SOURCE: Pew Research Center for the People and the Press, Biennial Media Consumption Survey, 2002.

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Categories of News Sought Online. Categories of news sought online have changed somewhat over the years (Pew Research Center for the People and the Press 2002a). The most popular category in 2002 was weather, followed by science and health (table 7-2). Technology, which topped the list in 1996, ranked fourth in 2002, just below international news. (Interest in international news grew 10 percentage points between 2000 and 2002, possibly because of the events of September 11, 2001.)

Internet users and nonusers have different news interests. In 2002, Internet users were more likely than nonusers to be interested in news about S&T, business and finance, international affairs, culture and arts, and sports, and they were less likely than nonusers to be interested in news about religion and crime. The S&T category had the greatest difference: 21 percent of Internet users said they followed news about S&T very closely, compared with 11 percent of nonusers[14] (table 7-3).

Science Information on the Internet. Although the Internet is not the leading source of news, it is now the preferred source when people are seeking information about specific scientific issues. In the 2001 NSF survey, when asked where they would go to learn more about a scientific issue such as global warming or biotechnology, 44 percent of respondents chose the Internet as their preferred source. About half as many (24 percent) chose books or other printed material, an indication that encyclopedias and other reference books are now taking a back seat to the Internet as research tools for the general public. No other source scored above 10 percent. (See figure 7-1, appendix table 7-3, and sidebar, "Science and the Internet.")

Table 7-2
Use of Internet as source of news: 1996–2002
(Percent)

Type of news	1996	1998	2000	2002
Weather	47	48	66	70
Science and health	58	64	63	60
International	45	41	45	55
Technology	64	60	59	54
Political	46	40	39	50
Business	53	58	53	48
Entertainment	50	45	44	44
Sports	46	39	42	47
Local	27	28	37	42

SOURCE: Pew Research Center for the People and the Press, Biennial Media Consumption Survey, 2002.

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[14] Experienced Internet users reported spending 5.5 percent of their online time looking up medical information and 7.5 percent of their time on the news (Cole 2002).

Table 7-3
News followed by American public, by Internet user status: 2002
(Percent)

Type of news	All respondents	Use Internet	Do not use Internet
Community	31	31	31
Crime	30	29	33
Health	26	25	27
Sports	25	26	23
Local government	22	22	22
International affairs	21	23	17
Washington news	21	22	20
Religion	19	16	24
Science/technology	17	21	11
Business/finance	15	17	11
Entertainment	14	14	12
Consumer news	12	13	11
Culture and arts	9	11	7

SOURCE: Pew Research Center for the People and the Press, Biennial Media Consumption Survey, 2002.

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Newspapers and Newsmagazines

The decline in newspaper readership during the past decade has been well documented. In addition, newspapers have reduced the number of reporters specializing in science and the amount of space devoted to stories about science (Girshman 2002).[15]

Surveys conducted by the Pew Research Center show that the percentage of Americans responding positively to the question “do you happen to read any daily newspaper or newspapers regularly, or not” declined from around 70 percent or more in the early and mid-1990s to 63 percent in the early 2000s. Responses to another question, “did you get a chance to read a daily newspaper yesterday,” showed a similar pattern: those answering “yes” fell from approximately 50 percent in the mid-1990s to 41 percent in 2002. Data from NSF surveys indicate that newspaper readership has declined at all education levels.

The percentage of people who report regularly reading a weekly newsmagazine such as *Time*, *U.S. News and World Report*, or *Newsweek* fell from a high of 24 percent during the mid-1990s to 13 percent in 2002; the amount of time spent reading these magazines also declined (Pew Research Center for the People and the Press 2002a).

The leading science magazines in the United States (according to sales figures) are *Popular Science*, *Discover*, *Scientific American, Wired, Natural History, Science News, Astronomy,* and *Science*. A total of 4.4 million copies of these publications are sold each month, with *Popular Science* accounting for 1.5 million, *Discover* about 1 million, and *Scientific American* approximately 700,000. The vast majority of both subscribers and readers of science magazines are men, and they tend to be well educated and have high incomes. For example, 85 percent of the readers of *Scientific American* have college degrees, and 60 percent have graduate or professional degrees. Readers of *Wired* have the highest average household income: $132,000. The average age of science magazine readers is in the 40s: 49 for *Scientific American* and *Discover*, 43 for *Popular Science*, and 41 for *Wired* (Wertheim 2003).

Science and the Internet

Various surveys offer insights into the public’s use of the Internet as a source of general or scientific/health-related information:

- **Why use the Internet?** According to a survey conducted in 2002, 28 percent of very experienced Internet users (6 or more years) said that the primary reason they started using the Internet was the “ability to get information quickly.” This was the highest percentage of any of the choices respondents were given; “for work” came in second at 24 percent, followed by “for school” at 14 percent. In addition, 61 percent of respondents said that the Internet is a very or extremely important source of information; 60 percent gave the same response for books, as did 58 percent for newspapers and 50 percent for television (Cole 2002).
- **Is Internet information accurate?** In a survey conducted in 2002, 50 percent of respondents said that most of the information on the World Wide Web is reliable and accurate, and 40 percent said that about half of the information is accurate. The comparable percentages for 2001 were 56 percent and 36 percent, respectively (Cole 2002).
- **Is Internet information trustworthy?** In another survey, when respondents were asked about their trust in various sources of information on medical and health research, the Internet came in last (at 56 percent), behind nurses (95 percent), pharmacists (94 percent), “your physician” (93 percent), medical schools and teaching hospitals (92 percent), “your dentist” (90 percent), voluntary health agencies (87 percent), media sources (63 percent), pharmaceutical companies (62 percent), and health maintenance or health insurance organizations (56 percent) (Research!America 2003).
- **How frequent are Internet visits?** In 2002, 18 percent of those surveyed said they had visited a website for science information once or twice during the past 30 days; 8 percent said three to five times and another 8 percent said more than five times (Davis, Smith, Marsden 2003).

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[15] Although most major newspapers have reduced science coverage, the *New York Times* may be an exception.

Books

People still read. In a recent survey, most respondents (75 percent) said that their use of the Internet has not affected the amount of time they spend reading books, newspapers, and magazines. About 20 percent said they spend less time reading because of the Internet, and 6 percent said they actually spend more time reading because of the Internet. Books rival the Internet as a very or extremely important source of information: almost identical numbers of respondents, three of five, made this claim. In addition, books were second only to television as a very or extremely important source of entertainment (Cole 2002).

Despite the expanding array of alternative sources of information, books continue to influence public debate and "are part of the media mix that permeates our culture" (Lewenstein 2002). Probably the most famous example of a science book influencing public debate was Rachel Carson's *Silent Spring,* which is widely credited with having started the environmental movement.

In addition to textbooks, handbooks, manuals, and conference proceedings that are written and produced for students and working scientists, there are science-related books meant for the general public, and some of these make bestseller lists and win prizes. By reaching a wider audience, they stimulate public and intellectual debate and contribute to popular culture. Other widely used books such as birdwatching guides and nature books spark interest in science among nonscientists. Self-improvement books about subjects such as diet, physical and mental health, and sex draw on medical, psychological, and other types of scientific research.

An indicator of increasing interest in scientific subjects among the book-reading public is the growing frequency with which science-related books make bestseller lists. Beginning in the late 1970s, such books began to appear more often on those lists and also started to win prizes on a regular basis. The release of Carl Sagan's *Dragons of Eden* marked a major milestone in the publication of books about science. It made the *New York Times* bestseller list in 1977 and won the Pulitzer Prize in the "general nonfiction" category in 1978. Thereafter, the number of science-related books added to the *Times* bestseller list in a typical year increased from fewer than 10 to more than 10, and books about science began receiving Pulitzer Prizes every year or every other year (figure 7-4 and table 7-4).

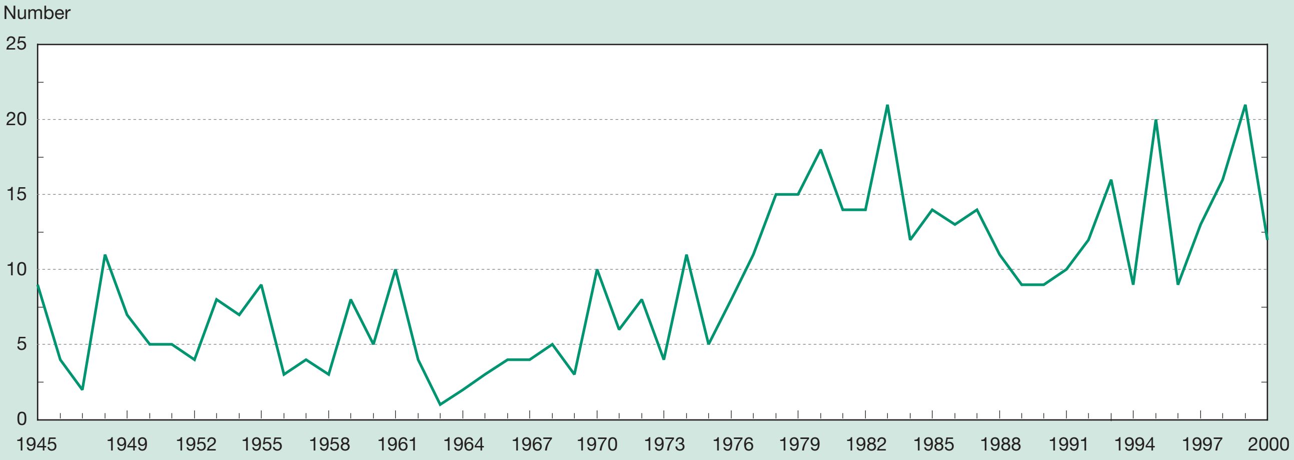
A few years after *Dragons of Eden* was published, another milestone was reached. Once again, Sagan was responsible. In 1980, his *Cosmos* became the first science-related book on the *Publishers Weekly* bestseller list to sell more than a half million copies. It was followed in 1988 by Stephen Hawking's *A Brief History of Time*, which has sold more than 9 million copies worldwide.

According to a science historian who has tracked the increasing popularity of books about science, an author's style and personality have a lot to do with whether a book reaches a wide, mainstream audience and becomes a bestseller (Lewenstein 2002). Sagan is a case in point. The success of his *Cosmos* was partially attributable to the popularity of the television series he hosted. The $2 million advance he subsequently received for his science fiction novel *Contact* was then the largest advance ever paid for a work of fiction.

Museums

Surveys show that S&T museums are more popular in the United States than in Europe. In 2001, 30 percent of NSF survey respondents said they had visited such a museum in the last 12 months, compared with only 11 percent of Europeans surveyed (European Commission 2001). When Europeans who had not visited an S&T museum were asked their reasons, a third said they were not interested in going

Figure 7-4
Science titles added to *New York Times* bestseller list: 1945–2000



SOURCE: B. Lewenstein, How science books drive public discussion, paper presented at conference, Communicating the Future: Best Practices for Communication of Science and Technology to the Public (Gaithersburg, MD, March 8, 2002).

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Table 7-4
Science-oriented Pulitzer Prize books after World War II

Award year	Title	Author	Category
1947	*Scientists Against Time*	Baxter	History
1967	*Exploration and Empire*	Goetzmann	History
1978	*Dragons of Eden*	Sagan	General nonfiction
1979	*On Human Nature*	Wilson	General nonfiction
1980	*Godel, Escher, Bach*	Hofstadter	General nonfiction
1982	*Soul of a New Machine*	Kidder	General nonfiction
1984	*Social Transformation of American Medicine*	Starr	General nonfiction
1986	*…The Heavens and the Earth*	McDougall	History
1988	*Launching of Modern American Science*	Bruce	History
1991	*Ants*	Holldobler & Wilson	General nonfiction
1995	*Beak of the Finch*	Weiner	General nonfiction
1998	*Summer for the Gods*	Larson	History
1998	*Guns, Germs, and Steel*	Diamond	General nonfiction
1999	*Annals of the Former World*	McPhee	General nonfiction

SOURCE: B. Lewenstein, How science books drive public discussion, paper presented at conference, Communicating the Future: Best Practices for Communication of Science and Technology to the Public (Gaithersburg, MD, March 8, 2002).

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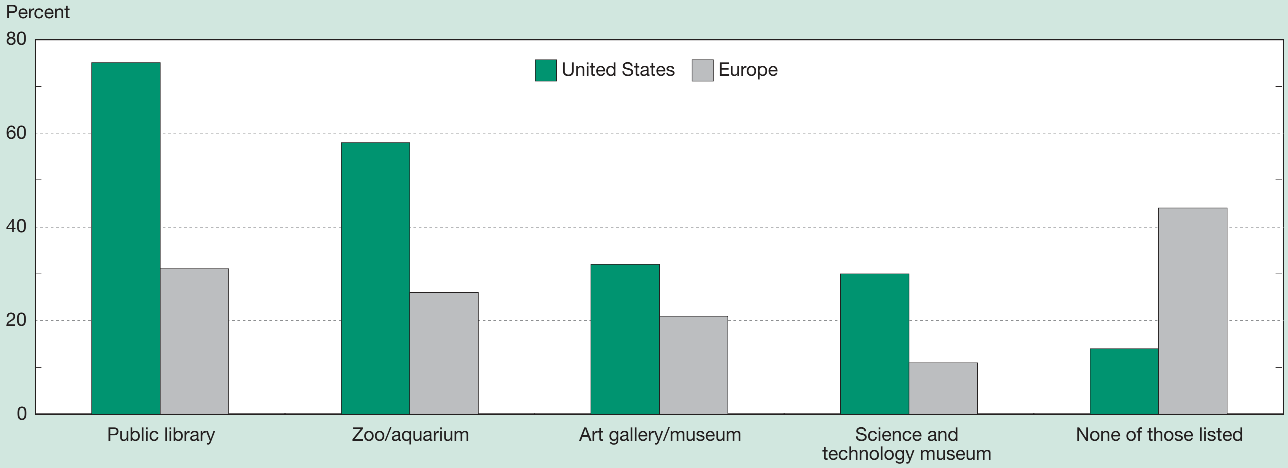
Figure 7-5
Type of establishment visited during past 12 months: 2001



SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology, 2001; and European Commission, Eurobarometer 55.2 survey and standard report, *Europeans, Science and Technology,* December 2001.

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and nearly as many said they did not have the time (only 3 percent said the entrance fee was too high).[16]

S&T museums are not the only public attractions that are less popular in Europe than in the United States. Europeans are also much less likely than Americans to visit zoos (26 versus 58 percent) and libraries (31 versus 75 percent) and are even less likely to visit art museums (21 versus 32 percent). Only 14 percent of surveyed Americans said they had not visited any of the four types of attractions during 2001, compared with nearly half (44 percent) of Europeans (figure 7-5).

Public Interest in S&T

Surveys conducted by NSF and other organizations consistently show that Americans are interested in issues related to S&T. Very few people admit to not being interested in these subjects. In 2001, about 45 percent of NSF survey respondents said they were very interested in new scientific discoveries and the use of new inventions and technologies. About the same number said they were moderately interested

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[16] Surveys conducted in the United Kingdom show that young people there are not interested in attending science-based attractions such as museums or in watching television programs about science. "Essentially, science is not a major thing in their world" (Burnet 2002).

in these subjects. Only about 10 percent were not interested at all.[17]

In Europe, 45 percent of survey respondents said they were "rather interested" in S&T, which is similar to the percentage of Americans who expressed an interest.[18] However, in sharp contrast to the 10 percent of American respondents who admitted disinterest in S&T, more than half (52 percent) of European respondents said they were not interested. U.S. and European findings coincided in two areas: more men than women expressed an interest in S&T, and respondents were more interested in medicine and the environment than in S&T in general.[19]

Despite the American public's professed interest in S&T issues, there is reason to believe that their interest may not be as strong as the data indicate. Surveys conducted by the Pew Research Center for the People and the Press show that community affairs, crime, health, and sports were the four types of news followed most closely by the American public in 2002; S&T ranked ninth, down two slots from its 2000 ranking. In addition, the level of interest in S&T (as measured by the percentage of survey respondents following related news very closely) declined between 1996 and 2002, along with an even greater decline for health-related stories (although these stories continued to rank high compared with other topics). In fact, by the same measure, interest in most subjects declined during the period; international affairs was an exception to this trend. (See table 7-5 and sidebar, "Few Science-Related News Stories Attract Public Interest.")

Still, interest in news about S&T is only part of the story. Other indicators discussed earlier in this chapter, including the popularity of S&T museums and the growing number of science-related books on bestseller lists, suggest that many people are interested in science even though they may not follow science news.

Table 7-5
News followed very closely by American public: 1996–2002
(Percent)

Type of news	1996	1998	2000	2002
Community	35	34	26	31
Crime	41	36	30	30
Health	34	34	29	26
Sports	26	27	27	25
Local government	24	23	20	22
Washington news	16	19	17	21
International affairs	16	16	14	21
Religion	17	18	21	19
Science and technology	20	22	18	17
Business and finance	13	17	14	15
Entertainment	15	16	15	14
Consumer news	14	15	12	12
Culture and arts	9	12	10	9

SOURCE: Pew Research Center for the People and the Press, Biennial Media Consumption Survey, 2002.

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The Public's Sense of Being Well Informed About S&T Issues

In general, most Americans do not think they are well informed about S&T issues. In the 2001 NSF survey, fewer than 15 percent of respondents described themselves as being very well informed about new scientific discoveries and the use of new inventions and technologies; approximately 30 percent considered themselves to be poorly informed.[20] Americans felt better informed about local school issues, economic issues and business conditions, new medical discoveries, and environmental pollution. On some types of issues, people felt less informed in 2001 than they used to. This downward trend is particularly noticeable for the five S&T-related issues included in the survey: new medical discoveries, new scientific discoveries, the use of new inventions and technology, space exploration, and environmental pollution (appendix table 7-4).

The European public also feels uninformed about S&T. In 2001, most Europeans (61 percent) said they felt poorly informed; one-third felt well informed. Europeans were more likely to feel well informed about sports, culture, and politics than about S&T issues and about as likely to feel uninformed about economics and finance as about S&T (European Commission 2001).

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[17] Other surveys had similar findings (VCU Center for Public Policy 2003). When asked about their interest in scientific discoveries, only 10 percent of respondents said they were "not much interested," and only 3 percent said they were "not at all" interested; 44 percent said they had "a lot" of interest, and 43 percent reported "some" interest.

[18] In Europe, the greatest interest in S&T tended to be in countries with relatively large numbers of college graduates, including Sweden (64 percent interest in S&T), Denmark (61 percent), the Netherlands (59 percent), and France (54 percent). Conversely, relatively low interest was found in countries with fewer college graduates, such as Ireland (32 percent interest) and Portugal (38 percent). Exceptions to this general relationship between higher education and interest in S&T were Greece, where interest was high (61 percent), and Germany, where interest was low (30 percent).

[19] The American public is very likely to read or listen to news about public health issues. For example, in a Research!America survey, 71 percent of respondents said they were very likely to read or listen to news about medical breakthroughs in treatments for diseases, 67 percent said the same about public health crises, and 60 percent said they were likely to pay attention to news about research that keeps people free from disease (Research!America 2002).

In Europe, survey respondents with a high level of formal education were more likely than others to say they were interested in the environment. In contrast, there was no association between education and level of interest in medicine. The Internet ranked third among the S&T developments of greatest interest to Europeans (European Commission 2001).

[20] In another survey conducted in 2001, only 11 percent of respondents described themselves as "very informed" about scientific discoveries, 60 percent thought they were "somewhat informed," 24 percent answered "not very informed," and 4 percent said that they were not at all informed about scientific discoveries (VCU Center for Public Policy 2002).

Few Science-Related News Stories Attract Public Interest

For nearly 2 decades, the Pew Research Center for the People and the Press has been tracking news stories that attract public interest. Of the approximately 1,000 most closely followed news stories of 1986–2002, not many had anything to do with science and/or technology. And, of the few that did, most were about weather and other types of natural disasters (such as earthquakes) and health-related subjects—not about scientific breakthroughs and technological advances. It should be noted, however, that an engineering/technology story actually does top the list. In July 1986, 80 percent of those surveyed said they were closely following news about the explosion of the space shuttle Challenger—not a natural disaster, but a manmade one. Table 7-6 lists the most closely followed S&T-related stories of 2000–2002 (Pew Research Center for the People and the Press 2003).

In 2000, the leading science-related news story was the announcement that scientists had completed mapping the human genome. For a science story, this one attracted a relatively high level of interest: 16 percent of respondents said they were following the story very closely. Nevertheless, that percentage was about half that (31 percent) needed to make the top 10 list for 2000. The leading story for the year was increasing gas prices: 61 percent of respondents followed that story very closely (Pew Research Center for the People and the Press 2000b).

The events of September 11, 2001, had a dramatic effect on news consumption. The Pew Research Center's surveys show that the average percentage of respondents following a typical news story more than doubled, from 23 percent during the 1990s to 48 percent in 2001. And, the center's top 10 list for 2001 looks very different from lists compiled in previous years. Eight of the top 10 news stories of 2001 were terrorism related; the percentage of respondents who followed these stories ranged from 78 percent down to 51 percent. Two science-related stories—the anthrax scare and a weather-related story—just missed the top 10, ranking 12th and 13th (at 48 and 47 percent), respectively (Pew Research Center for the People and the Press 2001). (At 61 percent, the rising price of gas was the top non-terrorism-related story of 2001.)

In 2002, interest in terrorism declined, although terrorism-related stories continued to dominate the top 10 list. At 65 percent, the top story in 2002 was the sniper shootings in the Washington, D.C., area. Two science-related stories—hurricanes on the Gulf Coast and cases of West Nile virus—ranked 12th and 15th (at 38 and 34 percent), respectively, in 2002 (Pew Research Center for the People and the Press. 2002c).

Table 7-6
Science/technology-related news stories attracting most public interest: 2000–02
(Percent)

News stories	Public interest	Date question asked
Reports of anthrax in United States	47	Nov-01
Firestone tire recall	42	Oct-00
Winter weather in Northeast and Midwest	42	Jan-01
Reports of anthrax in United States	41	Nov-01
Hurricanes in Louisiana and Gulf of Mexico	38	Oct-02
Cases of West Nile virus	34	Sep-02
Bush decision on stem cell research	31	Aug-01
Federal ruling on Microsoft	28	Jun-00
Food and Drug Administration's decision on RU-486	26	Oct-00
Outbreak of foot-mouth disease in Europe	22	Mar-01
Midwest floods	20	Apr-01
Droughts in United States	19	Apr-02
Reports on AIDS in Africa	19	Jul-00
Worldwide AIDS epidemic	19	Aug-01
Hackers attacking websites	18	Feb-00
Mad cow disease in Europe	18	Aug-01
AOL-Time Warner merger	17	Jan-00
Government's plan for Microsoft	16	May-00
Mapping human genetic code	16	Jul-00
Earthquake in India	15	Feb-01
Missile defense system	15	May-01
Oil spill off coast of Spain	15	Dec-02
Reports of cloned baby by religious cult	14	Jan-03
Court ruling in Microsoft case	13	Apr-00
Floods in Mozambique	10	Mar-00
United Nations special session on AIDS	6	Jul-01

NOTE: Percents reflect respondents who said they followed the story "very closely." Because Pew Research Center surveys are conducted every 2 weeks, the "reports of anthrax" item appears twice in November 2001.

SOURCE: Pew Research Center for the People and the Press, News Interest Index, Public Attentiveness to News Stories: 1986–2002 (Washington, DC, 2003).

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Public Knowledge About S&T

Surveys conducted in the United States and Europe reveal that many citizens do not have a firm grasp of basic scientific facts and concepts, nor do they have an understanding of the scientific process. In addition, belief in pseudoscience (an indicator of scientific illiteracy) seems to be widespread among Americans and Europeans. Studies also suggest that not many Americans are technologically literate.

Importance of Scientific Literacy

Scientific literacy in the United States (and in other countries) is fairly low. (Scientific literacy is defined here as knowing basic facts and concepts about science and having an understanding of how science works.) The majority of the general public knows a little but not a lot about science. For example, most Americans know that the Earth travels around the Sun and that light travels faster than sound. However, few know the definition of a molecule. In addition, most Americans are unfamiliar with the scientific process.[21]

It is important to have some knowledge of basic scientific facts, concepts, and vocabulary. Those who possess such knowledge are better able to follow science news reports and participate in public discourse on science-related issues. An appreciation of the scientific process may be even more important. Understanding how ideas are investigated and analyzed is a sure sign of scientific literacy. It is valuable not only in keeping up with important science-related issues, but also in evaluating and assessing the validity of any type of information and participating meaningfully in the political process (Maienschein 1999).

As noted earlier in this chapter, the science community has expressed concern that the public's lack of knowledge about science may have far-reaching consequences. Experts in science communication have identified challenges and successes in efforts to address this lack of knowledge. (See sidebar, "Communicating Science to the Public.")

The benefits of scientific literacy have become increasingly apparent in the wake of a landmark 1993 Supreme Court decision that addressed how particular types of evidence should be handled in legal proceedings (Kosko 2002). A recent survey revealed that many judges did not possess the knowledge necessary to determine whether evidence presented as scientific was, in fact, scientific. Seeking assistance in recognizing which scientific claims should be kept out of the courtroom, a group of judges recently approached a scientist who has spent part of his career helping the public distinguish valid from unfounded scientific claims. The judges asked the scientist to provide them with "indicators that a scientific claim lies well outside the bounds of rational scientific discourse." (See sidebar, "Science and the Law.")

Understanding Scientific Terms and Concepts

Neither Americans nor Europeans got high marks in a 2001 quiz designed to test their knowledge of science. Both groups were asked 13 questions. On average, Americans answered 8.2 questions correctly, compared with 7.8 for Europeans.[22] Americans scored higher than Europeans on seven of the questions (figure 7-6).

Response to one of the questions, "human beings, as we know them today, developed from earlier species of animals," may reflect religious beliefs rather than actual knowledge about science. In the United States, 53 percent of respondents answered "true" to that statement in 2001, the highest level ever recorded by the NSF survey. (Before 2001, no more than 45 percent of respondents answered "true.") The 2001 result represented a major change from past surveys and brought the United States more in line with other industrialized countries about the question of evolution.

During most of the 20th century, probably the most contentious issue related to the teaching of science has been whether and how evolution is to be taught in U.S. public school classrooms.[23] The controversy has continued in the new millennium, erupting in Ohio, Georgia, Texas, and elsewhere. Contention about this issue also surfaced in England in 2001. (See sidebar, "More Than a Century After Darwin, Evolution Still Under Attack in Science Classrooms.")

Neither the U.S. survey nor the Eurobarometer has shown much change in the public's level of knowledge about science, with one exception: the number of people who know that antibiotics do not kill viruses has been increasing. In 2001, for the first time, a majority (51 percent) of U.S. respondents answered this question correctly, up from 40 percent in 1995. In Europe, 40 percent of respondents answered the question correctly in 2001, compared with only 27 percent in 1992.[24]

The promising trend in knowledge about antibiotics and viruses suggests that a public health campaign to educate the public about the increasing resistance of bacteria to antibiotics has been working. This problem has been the subject of widespread media coverage,[25] and whenever the main culprit—the overprescribing of antibiotics—is mentioned, so is the fact that antibiotics are ineffective in killing viruses. In addition, parents of young children, especially those prone to ear infections, have been warned by their pediatricians

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[21] Researchers have concluded that fewer than one-fifth of Americans meet a minimal standard of civic scientific literacy (Miller, Pardo, and Niwa 1997).

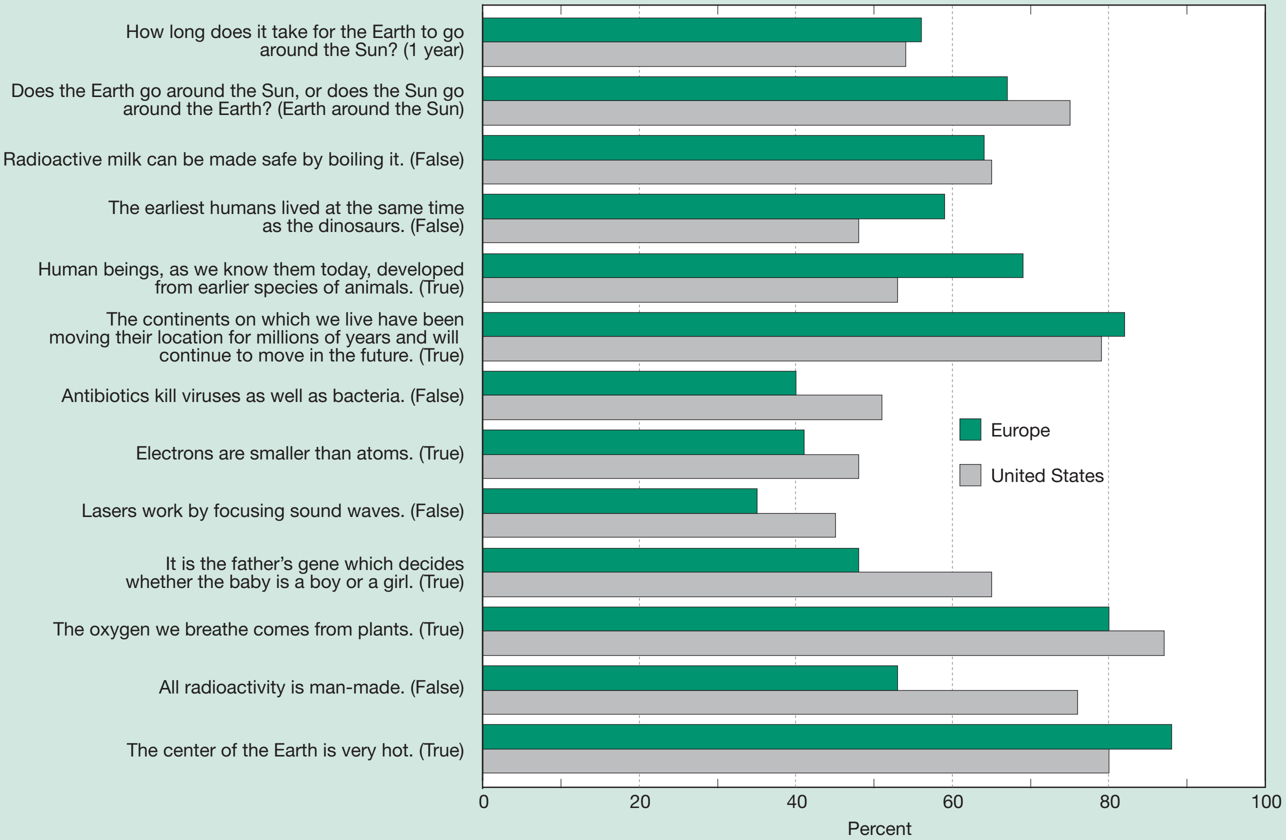
[22] In Europe, residents of Sweden, the Netherlands, Finland, and Denmark scored the highest, residents of Portugal, Ireland, Greece, and Spain the lowest.

[23] The National Science Board issued a statement on the subject in August 1999 (National Science Board 1999).

[24] Results from another survey indicate that most (93 percent) of the public has seen, heard, or read reports about the overuse of antibiotics causing a serious health problem. Although 79 percent of survey respondents were aware that colds and the flu are caused by viruses, not bacteria, and 61 percent knew that antibiotics are not effective in treating viruses, about half (49 percent) believed that antibiotics are at least somewhat effective in treating colds and the flu (Taylor and Leitman 2002).

[25] Recent examples include the outbreaks of severe acute respiratory syndrome (SARS) and monkey pox during 2003.

Figure 7-6
Public understanding of scientific terms and concepts: 2001



SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology, 2001; and European Commission, Eurobarometer 55.2 survey and standard report, *Europeans, Science and Technology*, December 2001.

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about this problem.[26] However, the message still has not reached a large segment of the population, in both the United States and Europe.

Americans apparently are also becoming more familiar with the terminology of genetics. In a 2001 NSF survey, 45 percent of respondents were able to define DNA. The percentage of correct responses to this survey question increased in the late 1990s, a trend that probably reflected the heavy media coverage of DNA use in forensics and medical research. More recently, a 2003 Harris poll found that 60 percent of adults in the United States selected the correct answer when asked "what is DNA?" (the genetic code for living cells), and two-thirds chose the right answer when asked "what does DNA stand for?" (deoxyribonucleic acid) (KSERO Corporation 2003).

Surveys also indicate that the American public lacks an appreciation of basic statistical concepts and terminology. If statistics were confined to academic journals and textbooks, this finding would be of limited interest. But daily newspapers and even television newscasts rely on tables and charts to illustrate all kinds of trends. (See sidebar, "Understanding Statistics.")

Understanding the Scientific Process

NSF surveys have asked respondents to explain in their own words what it means to study something scientifically. Based on their answers, it is possible to conclude that most Americans (two-thirds in 2001) do not have a firm grasp of what is meant by the scientific process.[27] This lack of understanding may explain why a substantial portion of the population believes in various forms of pseudoscience. (See discussion of "Belief in Pseudoscience" in this chapter.)

In 2001, both the NSF survey and the Eurobarometer asked respondents questions designed to test their knowledge of how an experiment is conducted and their understanding

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[26] A recent study found that the number of prescriptions for antibiotics for children in the United States declined significantly between 1996 and 2000 (Finkelstein et al. 2003) and that parents who demand antibiotics for their children's ear infections can be swayed by doctors to change their minds (Siegel 2003).

[27] Correct explanations of scientific study include responses describing it as theory testing, experimentation, or rigorous, systematic comparison.

Communicating Science to the Public

Experts in science communication agree that there is no general audience for information about science and technology (S&T). Messages must be tailored to the needs and knowledge levels of specific audiences, especially policymakers, the press, researchers, and the "science-attentive" public (i.e., people who are interested in and knowledgeable about science, which is 10 percent of the population, according to the 2001 National Science Foundation survey).[*]

Science communicators cite two recent trends that have had a major impact on their profession:

- **The Internet has revolutionized communication.** Science communicators no longer have to depend on television and print reporters. The impact of the Internet on information dissemination has been so monumental that it is often likened to that of television, which, a generation earlier, also revolutionized communication with the public by bringing visual images into people's living rooms (Cole 2002).
- **News reporting has become increasingly fragmented.** Network news broadcasts and big-city daily newspapers no longer dominate news coverage the way they used to. Science communicators must focus on providing the types of news and information required by a relatively small group of specialized reporters. This requires focusing more on the type of news and information needed by such reporters and less on what the press can do to serve the needs of the science community (Borchelt 2002).

In March 2003, communicators gathered at a conference sponsored by the U.S. Department of Energy and the National Institute of Standards and Technology (NIST). Their main purpose was to identify best practices for communicating information about S&T to the public. A related report (NIST 2002) identifies successful communication programs (based on audience size, number of Web hits, and length of support) and attributes their success to several practices:

- Illustrating both the process and the product of science
- Involving scientists in a substantial way[†]
- Considering the political climate and/or involving decisionmakers[‡]
- Using multimedia, illustrations, and interactivity to bring science to life
- Relating science to the everyday environment
- Avoiding parochialism[§]
- Viewing the topic from the audience's point of view, not the institution's
- Using face-to-face methods
- Reaching out beyond the science-attentive public
- Providing information to the commercial media in easily usable form

According to the NIST report, public education campaigns are being carried out by many of the corporations, hospitals, and government agencies that fund and conduct research. The report also notes that many outreach and education programs sponsored by government laboratories and academic institutions are premised on the assumption that the public has a right to know how its tax dollars are being used.

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[*] Science-attentive members of the public are most likely to be male, young, and affluent. They are also likely to vote, be politically active, be savvy about technology, and understand scientific information with minimal explanation (Borchelt 2002).

[†] Communicators may encounter resistance when they attempt to involve scientists. A recent survey of scientists (Sigma Xi Membership Poll, conducted with Research!America in 2001) found that 42 percent engaged in no public outreach. Asked why, 76 percent said they did not have time, 28 percent did not want to, and 17 percent did not care. Only 12 percent of the surveyed scientists said they were engaged in political outreach, and 20 percent were in contact with the media.

[‡] A well-designed communication campaign can minimize public and political opposition to new technologies. Such a campaign spelled success for The Orange County (California) Water District's plan to use treated wastewater as a source of drinking water, a technology that failed to gain acceptance in other California communities (Ferch 2002).

[§] Universities tend to limit their Web-based science reporting to their own research activities. But at the University of Wisconsin–Madison, The Why Files website draws on stories from all sources for its popular "science behind the news" coverage (Devitt 2002).

of probability—two important aspects of scientific literacy.[28] Only 43 percent of Americans and 37 percent of Europeans answered the experiment question correctly. Both groups did better with probability: 57 percent of Americans and 69 percent of Europeans answered that question correctly.

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[28] The question pertaining to experimental evaluation was: "Now, please think of this situation. Two scientists want to know if a certain drug is effective in treating high blood pressure. The first scientist wants to give the drug to 1,000 people with high blood pressure and see how many experience lower blood pressure levels. The second scientist wants to give the drug to 500 people with high blood pressure, and not give the drug to another 500 people with high blood pressure, and see how many in both groups experience lower blood pressure levels. Which is the better way to test this drug? Why is it better to test the drug this way?"

The text of the probability question was: "Now think about this situation. A doctor tells a couple that their 'genetic makeup' means that they've got one in four chances of having a child with an inherited illness. Does this mean that if their first three children are healthy, the fourth will have the illness? Does this mean that if their first child has the illness, the next three will not? Does this mean that each of the couple's children will have the same risk of suffering from the illness? Does this mean that if they have only three children, none will have the illness?"

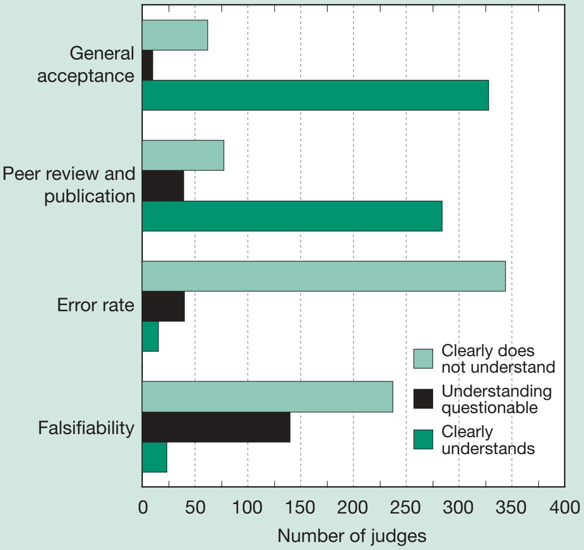
Because the Eurobarometer report was translated from French to English, the question wordings may not have been identical to those in the NSF survey. However, approximate comparisons are possible.

Science and the Law

In 1993, the U.S. Supreme Court issued a landmark decision in the case of *Daubert* v. *Merrell Dow Pharmaceuticals*. *Daubert* articulated standards judges should use (falsifiability, error rate, peer review, and general acceptance) to determine the admissibility of expert testimony in court. It affirmed that judges had a responsibility to be gatekeepers, keeping evidence that did not meet these standards out of the courtroom.* For example, applying the Daubert guidelines, judges have excluded handwriting analysis as evidence in a number of cases (Adams 2003).

One of the issues raised by the *Daubert* decision was whether judges could fulfill their new gatekeeping function. Did they know enough about science and the scientific method to be able to apply the *Daubert* guidelines? A few years ago, a team of researchers attempted to find out (Dobbin et al. 2002). To assess how well judges understood the four standards prescribed in *Daubert,* the researchers surveyed 400 state trial court judges in all 50 states. A majority of the judges clearly understood peer review and general acceptance, but only a fraction clearly understood falsifiability and error rate (figure 7-7). The survey results suggest that "many judges may not be fully prepared to deal with the amount, diversity and complexity of the science presented in their courtrooms" and that "many judges did not recognize their lack of understanding" (Gatowski et al. 2001).

Figure 7-7
Understanding of *Daubert* guidelines for admitting scientific evidence: 2001



SOURCE: S. Gatowski et al. 2001. Asking the gatekeepers: A national survey of judges on judging expert evidence in a post-*Daubert* world. *Journal of Law and Human Behavior* 25(5): 433–58.

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Acknowledging that most members of the judiciary do not have a scientific background, the Supreme Court recommended that judges obtain outside expertise to guide them in their gatekeeper responsibilities. The Court suggested that judges ask organizations such as the National Academy of Sciences and the American Association for the Advancement of Science for assistance in identifying experts to review scientific testimony before it is presented to juries. The latter now has such a project, Court Appointed Scientific Experts (CASE). In addition, the Federal Judicial Center publishes and distributes to federal judges a *Reference Manual on Scientific Evidence* that contains chapters on how science works, statistics, survey research, several aspects of medical science, and engineering (Federal Judicial Center 2000).

Furthermore, a group of judges recently asked renowned physics professor Robert L. Park for guidance on how to recognize questionable scientific claims. The author of a landmark book on the subject, Park came up with "seven warning signs" that a scientific claim is probably bogus (Park 2002):

1. The discoverer pitches the claim directly to the media (thus bypassing the peer review process by denying other scientists the opportunity to determine the validity of the claim).
2. The discoverer claims that a powerful establishment is trying to suppress his or her work. (The mainstream science community may be deemed part of a larger conspiracy that includes industry and government.)
3. The scientific effect involved is always at the very limit of detection.
4. The evidence for a discovery is anecdotal.
5. The discoverer says a belief is credible because it has endured for centuries.
6. The discoverer has worked in isolation.
7. The discoverer must propose new laws of nature to explain an observation.

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*In March 1999, in the case of *Kumho Tire Co., Ltd. et al.* v. *Carmichael et al.,* the Supreme Court ruled that the *Daubert* gatekeeping obligation applies not only to scientific testimony but to all expert testimony, including that of engineers (National Academy of Engineering 1999).

More Than a Century After Darwin, Evolution Still Under Attack in Science Classrooms

In 1999, the Kansas State Board of Education decided to delete evolution from the state's science standards. The action received widespread press coverage and sparked an outcry in the science community. Most of the public also disagreed with the decision, which was reversed after board members who had voted for the change were defeated in the next election.

Thus began another round of attacks on the teaching of evolution in public school classrooms. Similar eruptions have been occurring since the landmark 1925 Scopes "monkey" trial. Although Tennessee teacher John Scopes was convicted, science ended up being the true victor, according to the history books and thanks to the play *Inherit the Wind.* The next milestone occurred in 1987 when the Supreme Court struck down a Louisiana law that prohibited the teaching of evolution unless equal time was given to creationism.

Recently, controversy over the teaching of evolution has emerged in Kansas and nearly 20 other states. In general, the recent attacks on evolution have come from two directions: a push to introduce "intelligent design" in science classrooms as a viable alternative to evolution* and efforts to add evolution disclaimers to science textbooks.

In June 2001, the U.S. Senate adopted a "sense of the Senate" amendment to the Elementary and Secondary Education Act authorization bill (which later became known as the "No Child Left Behind Act"). Although the text of the amendment appeared to promote the development of students' critical thinking skills, it also contained the following sentence: "Where topics are taught that may generate controversy (such as biological evolution), the curriculum should help students to understand the full range of scientific views that exist." Concerned that the amendment was a thinly veiled attempt to inject the theory of intelligent design into science curriculums (because of the singling out of evolution as a controversial theory), nearly 100 science organizations mobilized in opposition to the amendment.[†] The amendment never made it into the final bill, but some of the language was included in the conference committee report. Although such text does not have the force of law, proponents of the intelligent design theory began to claim congressional endorsement in their efforts to persuade school boards in several states and localities to include the theory in science instruction (Palevitz 2002).

In 2002, Ohio's state school board became embroiled in a year-long controversy about the inclusion of evolution in the state's science education standards (Clines 2002). Although the board ultimately approved standards that strongly advocated the teaching of evolution, the door was left open for teachers to permit classroom discussions that treat intelligent design as an alternative to evolution (Sidoti 2002).

School boards in other states have also been involved in evolution-related controversies. In Georgia, the Cobb County school board decided to affix stickers to science textbooks stating that "evolution is a theory, not a fact, regarding the origin of living things." This was not the first such action. In 1996, Alabama began requiring evolution disclaimer stickers on biology textbooks. Similar statewide efforts were turned back in Louisiana (Maggi 2002) and Oklahoma (Cable News Network 2001). Although Alabama now has the only statewide policy, local governments in other states are using disclaimer stickers. Cobb County and other locales are facing legal challenges to the evolution disclaimers.[‡]

Controversy over the teaching of evolution has also affected institutions of higher education:

- A biology professor at a Texas university came under fire for religious discrimination when he posted a demand on his website that students who wanted a letter of recommendation from him for postgraduate studies had to "truthfully and forthrightly affirm a scientific answer" to the question of how the human species originated (Madigan 2003).
- In 2002, a new college in Virginia started primarily for home-schooled students was denied accreditation by the American Academy for Liberal Education because the college requires professors to sign a statement of faith that they will teach from a creationist perspective (Olsen 2002).

This kind of controversy is almost unheard of in other industrialized nations. However, that may be changing. For example, there was a recent uproar in England when teachers at a college were accused of giving preference to a creationism interpretation of biology.

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*The theory of intelligent design holds that life is too complex to have happened by chance and that, therefore, some sort of intelligent designer must be responsible. Critics claim that this theory is simply a more sophisticated form of creationism (which the courts have said may not be taught in public schools). They argue that intelligent design theory has nothing to do with science because its assertions are not falsifiable: they cannot be tested or observed and cannot undergo experimentation (Morris 2002). In contrast, "[evolution] has been directly observed in operation not only in the laboratory but also in the field. Where there is still room for argument and discussion is in the precise contributions of different mechanisms to evolutionary change. In this vibrant debate, intelligent design offers no meaningful contribution" (Greenspan 2002). According to Eugenie C. Scott, president of the National Center for Science Education, "There aren't any alternative scientific theories to evolution" (Watanabe 2002). In October 2002, the American Association for the Advancement of Science Board of Directors passed a resolution on intelligent design that "calls upon its members to assist those engaged in overseeing science education policy to understand the nature of science, the content of contemporary evolutionary theory and the inappropriateness of 'intelligent design theory' as a subject matter for science education" (Pinholster 2002).

[†] In 2001, the president of one of these organizations, Eugenie C. Scott of the National Center for Science Education, received the National Science Board Public Service Award for increasing public understanding of science and engineering.

[‡] Bruce Alberts, president of the National Academy of Sciences, asked 30 scientists and physicians in Georgia to lobby Cobb County board members to remove disclaimers (MacDonald 2002).

Understanding Statistics

Reports on scientific and medical studies, even those written for lay readers, often include supporting statistics and related terminology. In addition, many news articles discuss the results of public opinion polls and present survey findings in tables or graphs. Even though familiarity with basic statistical concepts can make the news more meaningful, many Americans lack that familiarity. Surveys conducted in 1987 by the Roper Organization and in 2002 by Child Trends, Inc., and the Annie E. Casey Foundation asked two questions designed to assess the public's knowledge of statistics. Both questions concerned "margin of error" information in reports on public opinion polls.

When asked whether they found the margin of error useful or were unsure what it meant, 40 percent of respondents in 2002 said it was useful (up from 25 percent in 1987) and 39 percent were unsure of its meaning (down from 48 percent in 1987); few said they understood it but did not find it useful (17 percent in 2002 and 14 percent in 1987).

Respondents were also asked to choose among four definitions of "what a 4% margin of error means." The percentage choosing the correct definition, "if every adult answered the questions, the results would very probably be within 4 points of those reported," nearly doubled between 1987 and 2002, from 16 to 30 percent. It should be noted, however, that the majority of respondents in both years answered incorrectly (more chose "including all possible sources of error, the results should be no more than 4 points off the mark" than the correct definition), an indication that most Americans do not have a strong grasp of this particular area of statistics.

Technological Literacy

Most Americans are probably not technologically literate. They have little conception of how science, technology, and engineering are related to one another, and they do not clearly understand what engineers do and how engineers and scientists work together to create technology. Those are the major findings of a recent report issued by the National Academy of Engineering (NAE) and the National Research Council (NRC) (Committee on Technological Literacy 2002). In addition, the International Technology Education Association (ITEA) concluded from its 2001 survey that "adults are very interested in but relatively poorly informed about technology" (Rose and Dugger 2002).[29]

In the NAE/NRC report, technological literacy was defined as "one's ability to use, manage, assess, and understand technology." The concept includes an understanding of the nature of technology, the design process, and the history of technology; a capacity to ask questions and make informed decisions about technology; and some level of hands-on capability related to the use of technology. (See sidebar, "Characteristics of a Technologically Literate Citizen.")

Characteristics of a Technologically Literate Citizen

The National Academy of Engineering and the National Research Council have identified the following indicators of technological literacy (Committee on Technological Literacy 2002):

Knowledge

- Recognizes the pervasiveness of technology in everyday life
- Understands basic engineering concepts and terms, such as systems, constraints, and tradeoffs
- Is familiar with the nature and limitations of the engineering design process
- Knows some of the ways in which technology shapes human history and people shape technology
- Knows that all technologies entail risk, some that can be anticipated and some that cannot
- Appreciates that the development and use of technology involve tradeoffs and a balance of costs and benefits
- Understands that technology reflects the values and culture of society

Ways of Thinking and Acting

- Asks pertinent questions, of self and others, regarding the benefits and risks of technologies
- Seeks information about new technologies
- Participates, when appropriate, in decisions about the development and use of technology

Capabilities

- Has a range of hands-on skills, such as using a computer for word processing, surfing the Internet, and operating a variety of home and office appliances
- Can identify and fix simple mechanical or technological problems at home or work
- Can apply basic mathematical concepts related to probability, scale, and estimation to make informed judgments about technological risks and benefits

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[29] Almost everyone surveyed agreed that technological literacy is an important goal. About three-fourths of the respondents said it is very important "for people at all levels to develop some ability to understand and use technology"; the remaining fourth said that it was somewhat important. Responses were similar for both sexes and all age groups.

According to the NAE/NRC report:

> Technology has become so user friendly it is largely "invisible." Americans use technology with a minimal comprehension of how or why it works or the implications of its use or even where it comes from. American adults and children have a poor understanding of the essential characteristics of technology, how it influences society, and how people can and do affect its development.

The report also notes that, "like literacy in reading, mathematics, science, or history, the goal of technological literacy is to provide people with the tools to participate intelligently and thoughtfully in the world around them." The following points are also made:

- Technological literacy is particularly important for decisionmakers in business, government, and the media. However, as the report notes, "there is no evidence to suggest that legislators or their staff are any more technologically literate than the general public."
- Technological literacy is extremely important to the health of the U.S. economy. Technological innovation is a major factor in the vitality of the economy, and an increasing number of jobs require workers to be technologically literate.

Although discussions of technological literacy imply agreement about the definition of technology, many people define technology far too narrowly. Their definition is usually restricted to computers and the Internet.[30]

In the ITEA survey, respondents were asked to name the first word that comes to mind when they hear the word "technology." Approximately two-thirds said "computers." Moreover, when given a choice of two definitions for "technology," 63 percent chose "computers and the Internet," whereas 36 percent chose "changing the natural world to satisfy our needs." Younger people were more likely than older people to choose the broader definition.

A majority of survey respondents (59 percent) associated the word *design* (in relation to technology) with "blueprints and drawings from which you construct something" rather than "a creative process for solving problems." College graduates were more likely than others to choose the latter definition.

The ITEA survey results suggest that most Americans feel confident in their knowledge of technology. More than three-fourths of those interviewed said they could understand and use technology either to a great extent (28 percent) or to some extent (47 percent). Younger respondents and college graduates were more likely than others to feel confident about technology.

Respondents were also asked whether they thought they could explain how certain technologies work. Most (90 percent) said they could explain how a flashlight works, 70 percent could explain how a home heating system works, 65 percent could explain how a telephone call gets from point A to point B, and 53 percent could explain how energy is transferred into power.

For each example except the flashlight, women were less confident than men in their ability to explain the technology. Respondents who said they had a "great" understanding of technology and those who held technology- or computer-related jobs were more likely than others to say they could explain the technology in the four examples.

Despite their apparent confidence about explaining how various technologies work, respondents had difficulty answering specific questions. About half (51 percent) did not know that using a portable phone while in the bathtub does not create a risk of electrocution, and only a fourth (26 percent) knew that FM radios operate free of static. However, 82 percent knew that a car operates through a series of explosions, and 62 percent knew that a microwave oven does not heat food from the outside to the inside.

Belief in Pseudoscience

Although S&T are held in high esteem throughout the modern world, pseudoscientific beliefs continue to thrive, coexisting alongside society's professed respect for science and the scientific process. The science community and those whose job it is to communicate information about science to the public have been particularly concerned about the public's susceptibility to pseudoscientific or unproven claims that could adversely affect their health, safety, and pocketbooks (NIST 2002).

Pseudoscience has been defined as "claims presented so that they appear [to be] scientific even though they lack supporting evidence and plausibility" (Shermer 1997, p. 33).[31] In contrast, science is "a set of methods designed to describe and interpret observed and inferred phenomena, past or present, and aimed at building a testable body of knowledge open to rejection or confirmation" (Shermer 1997, p. 17).

Belief in pseudoscience is relatively widespread.[32] For example, at least a quarter of the U.S. population believes in astrology, i.e., that the position of the stars and planets can affect people's lives. Although the majority (56 percent) of

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[30] Technology actually encompasses not only the tangible artifacts of the human-designed world (e.g., bridges, automobiles, computers, satellites, medical imaging devices, drugs, genetically engineered plants) but also the larger systems of which the artifacts are a part (e.g., transportation, communications, health care, food production), as well as the people and infrastructure needed to design, manufacture, operate, and repair the artifacts.

[31] According to one group studying such phenomena, pseudoscience topics include yogi flying, therapeutic touch, astrology, fire walking, voodoo magical thinking, alternative medicine, channeling, Carlos hoax, psychic hotlines and detectives, near-death experiences, unidentified flying objects and alien abductions, the Bermuda Triangle, homeopathy, faith healing, and reincarnation (Committee for the Scientific Investigation of Claims of the Paranormal).

[32] A February 2002 CBS News poll found that 57 percent of Americans believe "that there are such things as ESP [extrasensory perception] or telepathy, or other experiences that can't be explained by normal means" (CBS News 2002). A Harris poll conducted in February 2003 revealed that 84 percent of those surveyed believed in miracles, 51 percent in ghosts, 31 percent in astrology, and 27 percent in reincarnation. Women and those with less formal education were more likely than others to believe in these paranormal phenomena (Taylor 2003).

those queried in the 2001 NSF survey said that astrology is "not at all scientific," 9 percent said it is "very scientific" and 31 percent thought it is "sort of scientific" (figure 7-8 and appendix table 7-5).

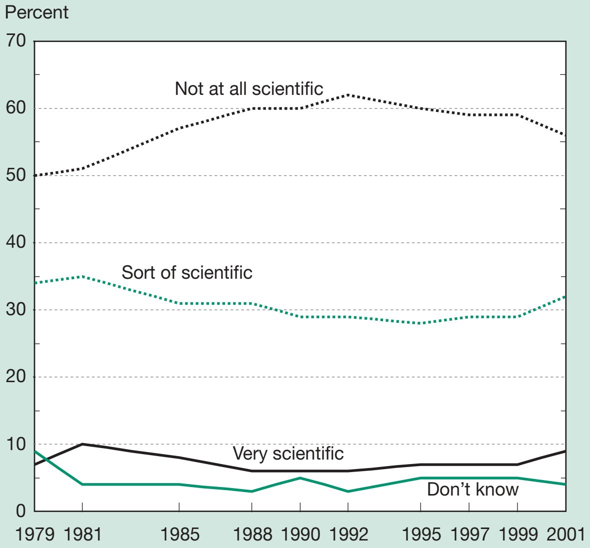
Belief in astrology is more prevalent in Europe, where 53 percent of those surveyed thought it is "rather scientific" and only a minority (39 percent) said it is not at all scientific (European Commission 2001). Europeans were more likely to say that astrology is scientific than to say the same about economics: only 42 percent of those surveyed thought that economics was scientific. Disciplines most likely to be considered scientific by Europeans were medicine (93 percent), physics (90 percent), biology (88 percent), astronomy (78 percent), mathematics (72 percent), and psychology (65 percent). History (33 percent) was at the bottom of the list. (Comparable U.S. data on the various disciplines do not exist.)

In the United States, skepticism about astrology is strongly related to level of education: 74 percent of college graduates said that astrology is "not at all scientific," compared with 45 percent of those with less than a high school education and 52 percent of those who had completed high school but not college. In Europe, however, respondents with college degrees were just as likely as others to claim that astrology is scientific.

Europeans were more likely than Americans to agree that "some numbers are particularly lucky for some people." The percentages were 46 percent and 32 percent, respectively.

Surveys conducted by NSF and other organizations suggest that at least half of the U.S. public believes in the existence of extrasensory perception (ESP), and a sizable minority believes in unidentified flying objects and that aliens have landed on Earth. In the 2001 NSF survey, 60 percent of respondents agreed that "some people possess psychic powers or ESP," and 30 percent agreed that "some of the unidentified flying objects that have been reported are really space vehicles from other civilizations."

Figure 7-8
Public assessment of astrology: 1979–2001



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology, various years. See appendix table 7-5.

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Surveys even show increasing belief in pseudoscience (Newport and Strausberg 2001). Of the 13 paranormal phenomena included in a periodically administered Gallup survey, belief in 8 increased significantly between 1990 and 2001, and belief in only 1 (devil possession) declined. Belief in four of the phenomena (haunted houses, ghosts, communication with the dead, and witches) had double-digit percentage point increases between 1990 and 2001[33] (figure 7-9).

Public Attitudes About Science-Related Issues

Public attitudes about science are generally more positive in the United States than in Europe, although both Americans and Europeans strongly support government funding for basic research. Recently, the public has grappled with controversial developments in biotechnology, especially human cloning and stem cell research. (The vast majority of Americans oppose the former, but attitudes about the latter are mixed.) Regardless of their attitudes about these and other science-related issues, the American public's confidence in the science community has remained high for several decades.

S&T in General

In general, Americans have highly favorable attitudes regarding S&T. In the Virginia Commonwealth University (VCU) 2002 Life Sciences Survey, 86 percent of respondents agreed that developments in science have helped make society better, and 90 percent agreed that "scientific research is essential for improving the quality of human lives" (VCU Center for Public Policy 2002).[34]

Americans seem to have more positive attitudes about the benefits of S&T than are found in Europe, as reflected in levels of agreement with various statements in the 2001 NSF and Eurobarometer surveys:

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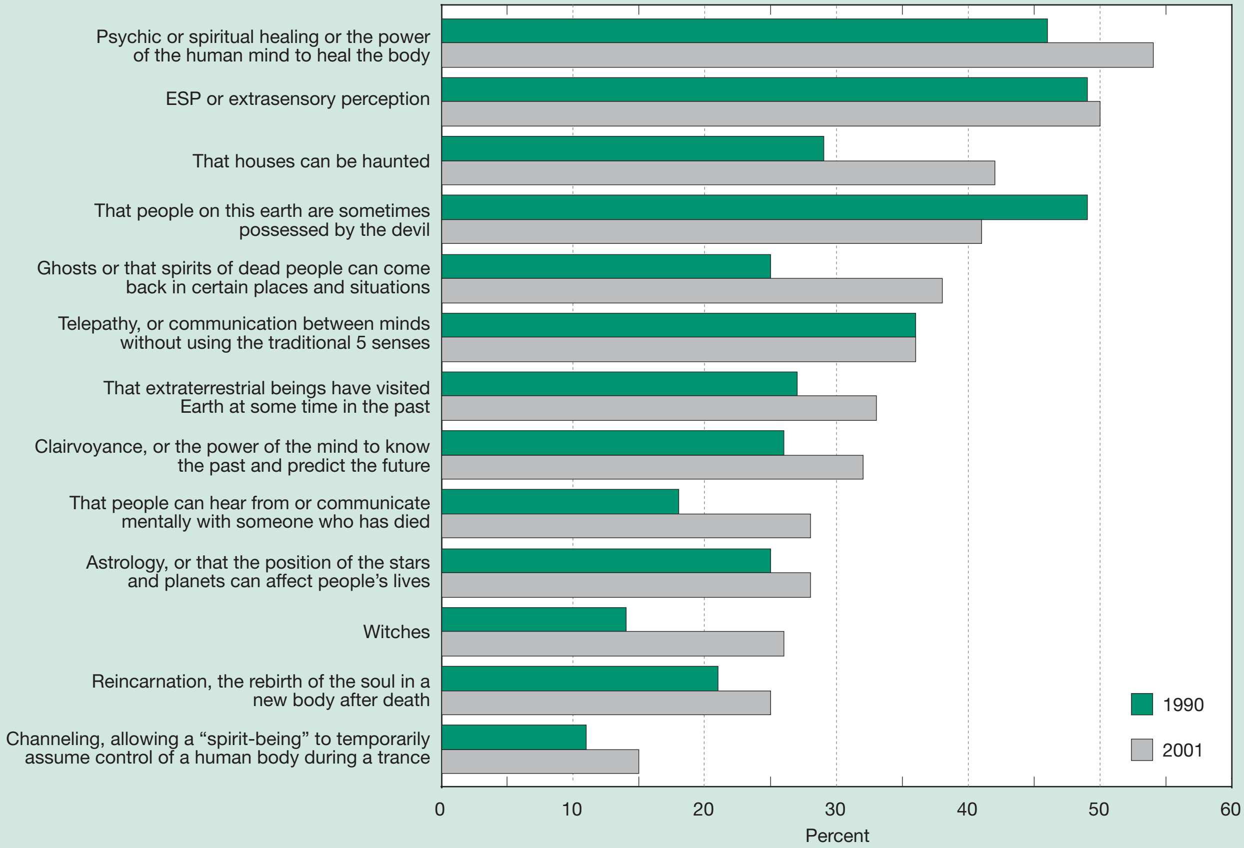
[33] Various researchers have demonstrated that a continuing parade of paranormal depictions in movies and psychic mediums on television distort some viewers' perception of reality and thus fuel such beliefs (Sparks, Nelson, and Campbell 1997; and Nisbet et al. 2002).

[34] When respondents were asked to name the development in science over the last 30 years that "has made the most positive contribution to society," 27 percent said medical and health (including vaccines, research, devices, and medicines), 24 percent said computers and/or the Internet, 5 percent said mass communication (including cell phones, satellites, TV, and radio), and 2 percent said biotechnology (including cloning, embryo research, DNA, and genetic research). When asked to name the development that has had the most negative effect on society, fewer respondents could provide an example (50 percent, compared with the 70 percent who named a positive development), and no single response stood out. The items that received the most votes as negative contributions were mass communication (8 percent), computers and the Internet (6 percent), weapons (5 percent), and nuclear weapons (4 percent) (VCU Center for Public Policy 2002).

Figure 7-9
Belief in paranormal phenomena: 1990 and 2001



SOURCE: F. Newport and M. Strausberg, Poll analyses: Americans' belief in psychic and paranormal phenomena is up over last decade, Gallup Organization (Princeton, NJ, 2001).

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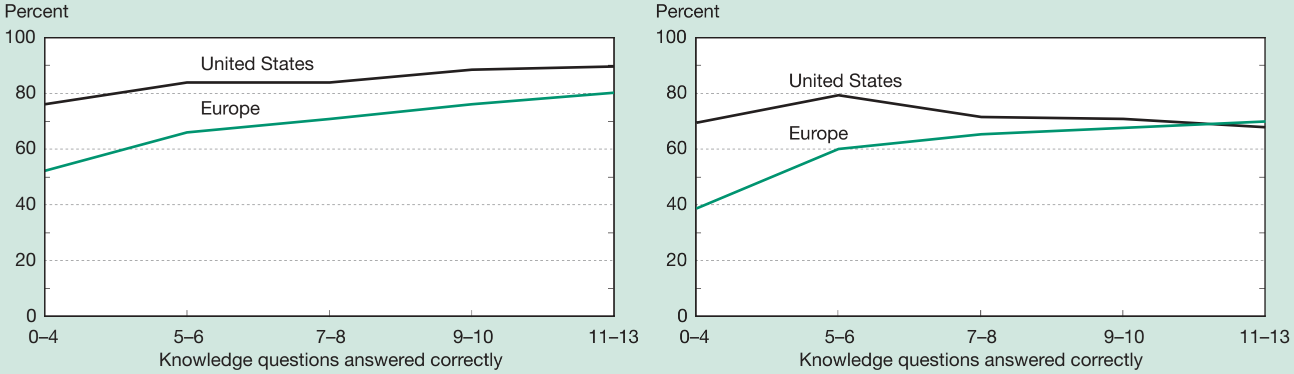
- **"Science and technology are making our lives healthier, easier, and more comfortable."** In the United States, 86 percent of respondents agreed, compared with 71 percent of Europeans. In addition, one of five Europeans disagreed, nearly twice the proportion of Americans who disagreed.
- **"With the application of science and technology, work will become more interesting."** In the United States, 86 percent agreed, compared with 71 percent in Europe.
- **"Thanks to science and technology, there will be greater opportunities for future generations."** In the United States, 85 percent agreed, compared with 72 percent in Europe.
- **"The benefits of scientific research outweigh any harmful results."** In the United States, 72 percent agreed, compared with 50 percent in Europe. In addition, only one-tenth of Americans disagreed, compared with one-fourth of Europeans. Although the percentage of Americans agreeing with this statement has held steady at more than 70 percent since 1988, agreement has declined in Europe, falling 11 percentage points between 1992 and 2001.

Findings from the surveys also suggest certain relationships between knowledge of S&T and belief in its benefits. It seems that in Europe, the more people know about science (i.e., the more knowledge questions they answer correctly), the more likely they are to believe in its benefits (as reflected in their agreement with the four statements discussed above). If such a relationship exists in the United States, it generally is much weaker. Regardless of education level, Americans generally are more likely than Europeans to view S&T as beneficial. (For the most part, this difference is most apparent at the low end of the knowledge scale and lessens as knowledge scores increase.) The one exception to these general conclusions is the statement about the benefits of research outweighing harmful results. Here, the relationship between knowledge and agreement is stronger in the United States than in Europe, and the American–European differences in level of agreement are greater at the upper end of the knowledge scale than the lower end (figure 7-10).

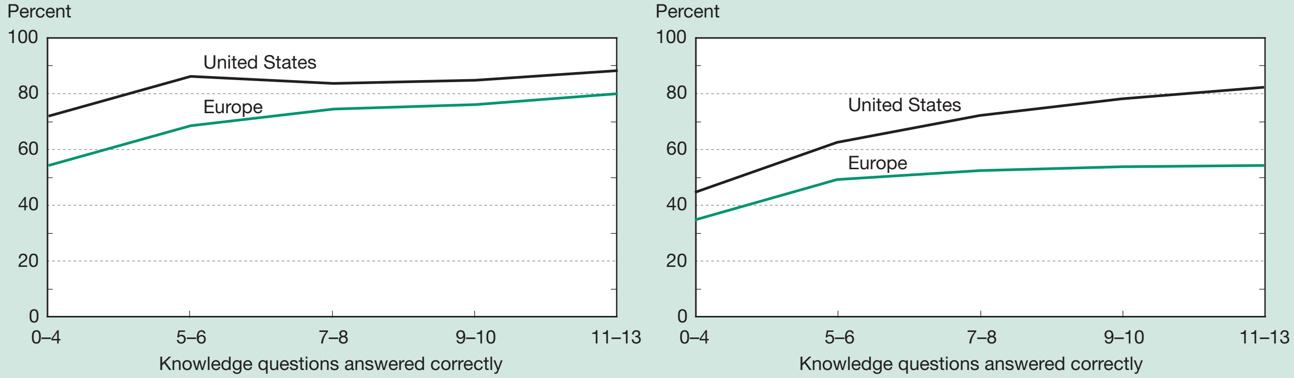
Despite Americans' highly favorable views about the benefits of S&T, a sizeable segment of the population has some reservations. In the 2003 VCU Life Sciences Survey, 63 percent of respondents agreed that "scientific research these days doesn't pay enough attention to the moral values

Figure 7-10
Public belief in benefits of science and technology, by level of related knowledge: 2001



Agreement that "science and technology are making our lives healthier, easier, and more comfortable"

Agreement that "with the application of science and technology, work will become more interesting"



Agreement that "thanks to science and technology, there will be greater opportunities for future generations"

Agreement that "the benefits of scientific research outweigh any harmful results"

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology, 2001; and European Commission, Eurobarometer 55.2 survey and standard report, *Europeans, Science and Technology*, December 2001.

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of society" (28 percent agreed strongly, 35 percent somewhat), and more than half agreed that "scientific research has created as many problems for society as it has solutions" (19 percent agreed strongly, 36 percent somewhat). In the 2001 Life Sciences Survey, those who said that "religious beliefs provide…guidance in [their] day-to-day living" were considerably more likely than others to support both statements (VCU Center for Public Policy 2001). In Europe, 31 percent of those surveyed agreed that "Europeans should be less concerned with ethical questions relating to modern science and technology"; 46 percent disagreed.

Findings from the NSF and Eurobarometer surveys also reveal some reservations about S&T in both the United States and Europe:

- **"We depend too much on science and not enough on faith."** In the United States, 51 percent of respondents agreed with this statement, compared with 45 percent in Europe.
- **"Science makes our way of life change too fast."** In the United States, 38 percent agreed, compared with 61 percent in Europe.

In the United States, the more knowledgeable respondents were about science, the less likely they were to agree with these statements (figure 7-11).

Federal Funding of Scientific Research

All indicators point to widespread public support for government funding of basic research in the United States. This has been the case since at least the mid-1980s.

In 2001, 81 percent of NSF survey respondents agreed with the following statement: "Even if it brings no immediate benefits, scientific research that advances the frontiers of knowledge is necessary and should be supported by the Federal Government."[35] The stability of this measure of public support for basic research is noteworthy. The level of agree-

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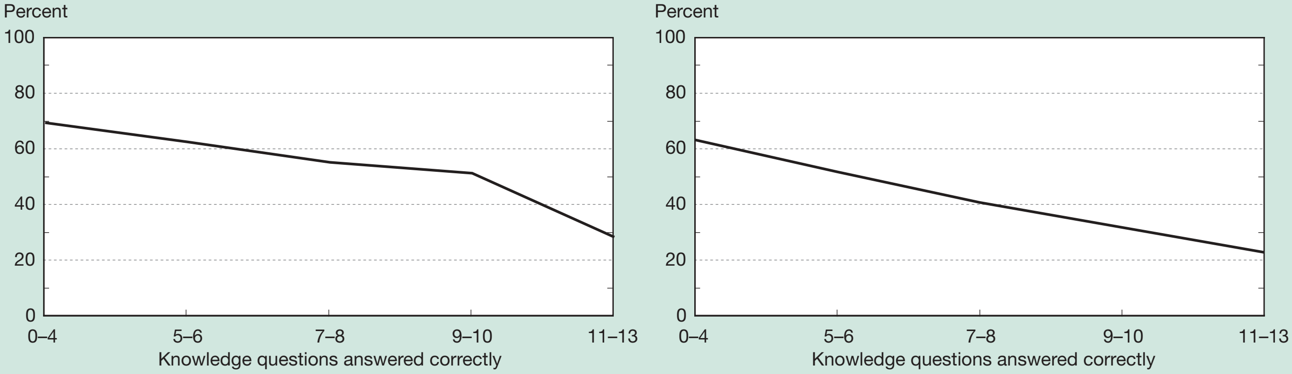
[35] Another survey found support for government funding of scientific research among 81 percent of respondents in 2001 (identical to the NSF survey result) and 75 percent in 2002 (Research!America 2002, 2003).

Figure 7-11
Public concerns about science and technology, by level of related knowledge: 2001



Agreement that "we depend too much on science and not enough on faith"

Agreement that "science makes our way of life change too fast"

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology, 2001.

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ment with this statement has consistently been around 80 percent since 1985. In addition, a consistently small percentage of respondents have held the opposite view. In 2001, 16 percent disagreed with the statement (appendix table 7-6).

Europeans also favor government investment in basic research. Seventy-five percent of those surveyed agreed with the above statement and only 10 percent disagreed. In addition, 83 percent of Europeans agreed that "basic scientific research is essential for the development of new technologies."

Although there is strong evidence that the American public supports the government's investment in basic research, few Americans can name the two agencies that provide most of the Federal funds for this type of research. In a recent survey, only 6 percent identified the National Institutes of Health as the "government agency that funds most of the medical research paid for by taxpayers in this country," and only 2 percent named NSF as "the government agency that funds most of the basic research and educational programming in the sciences, mathematics and engineering in this country." In the same survey, 67 percent could name the Food and Drug Administration as the "government agency that conducts the review and approval of new drugs and devices before they can be put on the market in this country," and 24 percent were able to name the Centers for Disease Control and Prevention as the "government agency whose primary mission is disease prevention and health promotion in this country" (Research!America 2002).

When Americans are surveyed about national priorities, scientific research is seldom one of their choices. Nevertheless, it is included as one of the priority choices in an ongoing Research!America survey. In the latest survey, 47 percent of respondents said that "more money for science research and engineering" was "very important"; that percentage was higher for all of the respondents' other four priority choices: education programs (84 percent), medical and health research (70 percent), Social Security and Medicare (73 percent), and tax cuts (50 percent) (Research!America 2003).[36] In the previous survey, most respondents said they would favor an elected official who supports increased funding for research (Research!America 2002).

In 2002, only 14 percent of NSF survey respondents thought the government was spending too much on scientific research; 36 percent thought the government was not spending enough, a percentage that has held relatively constant for more than a decade. To put the response on scientific research in perspective, it helps to look at the percentage who thought the government was not spending enough in other program areas: improving health care (75 percent) and education (74 percent), reducing pollution (60 percent), improving national defense (31 percent), and exploring space (12 percent) (appendix table 7-7).

The loss of the Columbia space shuttle in early 2003 apparently had little, if any, impact on public support for the U.S. space program. Public attitudes about manned space flight were strikingly similar to those recorded in 1986 after the loss of the space shuttle Challenger (see sidebar "Public Opinion in the Wake of the Columbia Space Shuttle Tragedy).

Support for increased government spending on research is more common in Europe than in the United States. When asked about the statement "public research budgets ought to be higher in Europe," 60 percent of Eurobarometer respondents agreed.

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[36] In the latest survey, about 60 percent of respondents supported doubling total national spending on government-sponsored medical research over the next 5 years; 30 percent did not support such an increase (Research!America 2003). Support for doubling spending decreased about 10 percent from the previous year's survey.

Public Opinion in the Wake of the Columbia Space Shuttle Tragedy

Loss of the Columbia space shuttle on February 1, 2003, did not have an immediate impact on public attitudes about the U.S. space program. In a Gallup survey conducted shortly after the tragedy, 82 percent of respondents expressed support for continuing the manned space shuttle program; only 15 percent favored ending the program (Moore 2003 and Newport 2003). These findings are almost identical to those recorded after the loss of the Challenger space shuttle in January 1986.

In addition, a majority of Americans continue to support funding for the National Aeronautics and Space Administration (NASA) and the U.S. space program. Nearly half (49 percent) of those surveyed after the Columbia tragedy thought funding should be maintained at its current level, and one-fourth favored an increase in funding. In the same poll, 17 percent thought funding should be reduced, and another 7 percent said the program should be ended altogether. These findings are not markedly different from those obtained in December 1999, when 16 percent of survey respondents favored increased funding for NASA, 49 percent wanted funding to stay at its current level, 24 percent favored a cutback, and 10 percent thought the U.S. space program should be terminated. The findings are also similar to those obtained after the loss of the Challenger. Americans also continue to favor manned over unmanned missions. After the loss of the Columbia, 52 percent of survey respondents said they favored manned missions, whereas 37 percent favored unmanned missions. Public opinion on manned versus unmanned exploration has changed little since 1990.

In the 2003 poll, 45 percent of respondents rated NASA's job performance as excellent, and 37 percent rated it as good; only 2 percent gave NASA a poor rating. In surveys conducted before 2003, no more than 26 percent of respondents ever rated NASA's performance as excellent (that high point occurred in 1998). The exceptionally high percentage of excellent ratings in 2003 may reflect the addition of the phrase "looking beyond the tragedy" to the survey question.

In other survey questions posed after the loss of the Columbia, nearly 60 percent of respondents said they were "deeply upset" by the event (similar to response after the Challenger accident), and about 70 percent said they had expected that "something like this would happen again sooner or later." When respondents were asked about their confidence in NASA's ability to prevent similar accidents in the future, 38 percent expressed a "great deal" of confidence, and 44 percent had a "fair amount" of confidence; again, this response is similar to that after the Challenger accident.

S&T Role in National Security

Americans are aware of the role of S&T in national security. According to one survey, 26 percent of the population is extremely or very concerned with the threat of biological or chemical terrorism such as anthrax or smallpox, 29 percent are somewhat concerned, and 45 percent are only slightly or not at all concerned. About 90 percent think that scientific research is either extremely or very important in preparing for and responding to threats of bioterrorism, and more than 80 percent strongly or somewhat support increased funding for such research (Research!America 2002).

Another survey, conducted by the Gallup Organization for the Bayer Corporation (2003), found that almost all adult Americans (96 percent) view S&T as playing a critical role in national security both domestically and internationally. When asked about the role of S&T in meeting future terrorist threats, 80 percent said that role is very important, and 17 percent said it is somewhat important.

Americans also are aware of the S&T role in specific aspects of national security, including military, intelligence, and law enforcement preparedness. More than 75 percent of survey respondents said that S&T plays a very important role in military and intelligence preparedness (about 20 percent said "somewhat important"), and 57 percent viewed the S&T role in law enforcement preparedness as very important. Most respondents said that the United States is either very or somewhat reliant on S&T for military preparedness (95 percent), intelligence preparedness (93 percent), and law enforcement preparedness (86 percent); the "very reliant" percentages were 63 percent, 57 percent, and 32 percent, respectively.

Americans also recognize the importance of a knowledgeable public in dealing with national security threats. Nine in 10 agreed that it is important for average Americans to be scientifically literate in order to understand and deal with nuclear terrorism, bioterrorism, and cyberterrorism.

Three-fourths of Americans also expect that the emphasis on national security after the events of September 11, 2001, will create new job opportunities in S&T for today's students. Survey respondents also agreed that it is either very important (62 percent) or somewhat important (33 percent) for those entering the new homeland security jobs to be scientifically literate, and 72 percent agreed that scientific literacy is more important for students now than it was before September 11. However, more than half of respondents (52 percent) were very concerned, and 38 percent were somewhat concerned, that today's students may lack "the math and science skills necessary to produce the science excellence required for homeland security and economic leadership in the 21st century."

Biotechnology and Medical Research

The introduction of new technologies based on genetic engineering is one of the few science-related public policy issues to raise controversy in recent years. From a nationwide recall of taco shells containing genetically modified corn not approved for human consumption to scientists promising to clone humans in the not-too-distant future, Americans have been trying to determine whether the potential benefits of biotechnology outweigh the risks. For example, the benefits of genetically modified food (increased productivity, longer shelf life, and reduced reliance on chemical pesticides) have been offset by concerns about health and environmental risks and consumers' right to choose what they eat. These controversies have also surfaced elsewhere in the world, often more dramatically than in the United States. (See sidebar, "European Public Opinion About Mad Cow Disease.")

European Public Opinion About Mad Cow Disease

Europeans believe that scientists are less to blame than others for the mad cow disease problem. About half (51 percent) of those surveyed agreed that scientists "bear a great deal of responsibility" (European Commission 2001). In contrast, 74 percent held the agri-food industry responsible, 69 percent blamed politicians, and 59 percent thought farmers were at fault. About half (45 percent) said they did not have enough information to say who is responsible. The higher their level of knowledge about science, the more likely Europeans were to blame the industry, politicians, and farmers and the less likely they were to blame scientists.

Asked what should be done to avoid such problems in the future, 89 percent thought that "scientists ought to keep us better informed about the possible hazards of certain scientific or technological advances," 86 percent said that scientists should "communicate their scientific knowledge better," 82 percent thought that the industry should be better regulated, and 72 percent thought that politicians should "rely more on the opinion of scientists."

International Attitudes About Biotechnology

Although antibiotechnology sentiments are more common in Europe than in the United States, optimism about biotechnology actually increased in Europe during recent years, as it did in the United States. These are the latest findings from a series of studies tracking U.S. and European public attitudes about biotechnology and its applications.[37]

In 2002, 69 percent of surveyed Americans thought that biotechnology would "improve our way of life in the next 20 years." This is a considerable gain over the 51 percent who expressed that view in 2000. In addition, the proportion who thought that biotechnology would "make things worse" in the next 20 years fell from 29 percent in 2000 to 11 percent in 2002. The pattern was similar in Europe, where the proportion of survey respondents who were optimistic about biotechnology increased from 38 percent in 1999 to 44 percent in 2002, while the proportion who were pessimistic dropped from 31 percent to 17 percent. In Europe, the gain in optimism after 1999 was enough to offset the downward trend of the preceding 8-year period, so that optimism is now back to its level of 10 years ago.

How do public attitudes about biotechnology compare with attitudes about other technologies? In 2002, 89 percent of Americans said that solar energy would "improve our way of life in the next 20 years," 88 percent held that view about computers, 82 percent about telecommunications, and 73 percent about the Internet. Expectations were less positive for space exploration (67 percent), cell phones (59 percent), nanotechnology (52 percent), and nuclear power (48 percent). In Europe, the pattern was similar, although the proportion of positive responses never exceeded 80 percent for any technology. Telecommunications, computers, and solar energy all scored in the 70s in Europe; mobile phones and the Internet scored about 10 percentage points lower; and several technologies scored in the 50s, including space exploration, nanotechnology, and nuclear energy (at 27 percent, the lowest).

What does the public think about the usefulness, risk, and moral acceptability of agricultural and medical applications of biotechnology? Data from surveys in Europe (1996, 1999, and 2002) and the United States (1997, 2000, and 2002) show the following:

- European attitudes about biotechnology in 1996 were about the same as U.S. attitudes in 1997. However, by 1999, there was a dramatic drop in European support for agricultural applications of biotechnology, including genetic engineering of foods (to make them higher in protein, increase their shelf-life, or improve their taste) and crops (to make them more resistant to insect pests). In contrast, U.S. public support for these applications remained virtually unchanged between 1997 and 2000.
- Between 1996 and 1999, there were moderate to large declines in public support for genetically modified foods and crops in nearly all European countries. The exceptions were Austria (foods and crops), Sweden (foods), and Spain (crops).
- By 2002, overall support for agricultural applications of biotechnology had changed little in either Europe or the United States. In the majority of European countries, support for genetically modified foods increased somewhat (by levels as high as 16 to 17 percent in Austria, Sweden, and the United Kingdom), while support remained stable

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[37] The U.S. survey was overseen in 1997 by Jon D. Miller, Chicago Academy of Sciences; in 2000 by Susanna Priest, Texas A&M University; and in 2002 by Toby Ten Eyck, Michigan State University. The European survey was conducted in 1996, 1999, and 2002 for the European Commission by George Gaskell, Martin Bauer, and Nick Alum.

in Germany and Finland and declined further in France, Italy, and the Netherlands.

- In both Europe and the United States, attitudes about medical applications of biotechnology (such as genetic testing to detect inherited diseases) have been significantly more positive than attitudes about agricultural applications. However, although the European and U.S. public continued to express high levels of support for medical applications in 2002, a significant minority of respondents in Europe had concerns about medical uses of genetic information: "Access to genetic information by government agencies and by commercial insurance is widely seen as unacceptable" (Gaskell, Allum, and Stares 2003). Other surveys are finding similar concerns in the United States (VCU Center for Public Policy 2001).
- In Europe, public support for medical applications of biotechnology is strongest in Spain and weakest in Austria.
- Public support for cloning human cells and tissues is stronger, and the subject far less controversial, in Europe than in the United States.

Public Support for Genetic Engineering

In no NSF survey year has a majority of Americans agreed that the benefits of genetic engineering outweigh the harmful results.[38] However, in the latest survey, approximately 9 of 10 respondents said they supported genetic testing to detect inherited diseases.[39] In addition, 6 of 10 supported the production of genetically modified food. Fewer than half supported cloning animals. NSF survey data show a slight, gradual decline in the American public's support for genetic engineering between 1985 and 2001. The shift can be seen most clearly among college-educated respondents and those classified as attentive to S&T issues.

Human Cloning and Stem Cell Research

The most recent survey data show that:

- The vast majority of Americans oppose the cloning of human beings.
- There is no consensus on medical research involving human embryonic stem cells. Although public opinion has fluctuated since 2001, it seems to be fairly evenly divided.

Human Cloning. All recent surveys that measure public opinion on human cloning have yielded similar findings: about four out of five Americans say they are opposed, and most of those say they are strongly opposed. In one survey, 65 percent of respondents said they were strongly opposed to human cloning, and only 13 percent said they favored it (VCU Center for Public Policy 2003).

Opposition to human cloning seems to be based on moral objections, not safety concerns. In a 2003 survey, 90 percent of respondents said they believed that cloning of humans is morally wrong; only 8 percent said it was morally acceptable. Public opinion on this subject has held steadfast since 2001 (Gallup 2003).

In 2002, 7 out of 10 respondents agreed that it is morally wrong "for businesses to use human cloning technology in developing new products"; only 19 percent thought this was morally acceptable (VCU Center for Public Policy 2002). In 2003, 8 percent of respondents described themselves as having a "very clear" understanding of the difference between human reproductive cloning and human therapeutic cloning; 26 percent were "somewhat clear," 32 percent were "not very clear," and 33 percent were "not at all clear." (Therapeutic cloning refers to the use of cloning technology in medical research to develop new treatments for diseases.)

Opposition to cloning crosses all demographic boundaries. In the 2002 VCU survey, clear majorities of both college graduates and respondents who expressed a high level of interest in science said they were strongly opposed to human cloning and considered it morally wrong for businesses to use cloning technology in product development. Strong opposition to cloning was also found among respondents who said they clearly understood the difference between therapeutic and reproductive cloning.

Opposition to therapeutic cloning is not quite as strong as opposition to human cloning in general: 32 percent of respondents in the 2003 VCU survey were strongly opposed to this use of cloning, 16 percent were somewhat opposed, 21 percent strongly favored it, and 29 percent somewhat favored it. Among respondents who said they clearly understood the difference between therapeutic and reproductive cloning, 46 percent opposed therapeutic cloning and 53 percent favored it; their views were similar to those of respondents who said they did not understand the distinctions. College graduates were somewhat less opposed than others to therapeutic cloning.

Stem Cell Research. Public opinion on stem cell research is not as clear cut as that on cloning. Recent survey findings on the subject are mixed.[40]

The public's interest in stem cell research apparently declined in 2002. When asked how much they had "seen, read, or heard" about medical research involving human embryonic stem cells, 13 percent of survey respondents said "a lot" (compared with 25 percent in 2001) and 20 percent said "nothing at all" (compared with 10 percent in 2001). In both years, about two-thirds of respondents answered "a little" or

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[38] In another survey conducted in 2001, however, 57 percent of Americans agreed that, overall, the benefits of conducting genetic research outweighed the risk, 27 percent said the opposite, and 13 percent said they didn't know. Most (83 percent) were very or somewhat confident that "new genetic research will lead to major advances in the treatment of diseases during the next 15 years" (VCU Center for Public Policy 2001).

[39] In another survey conducted in 2001, 77 percent of Americans agreed that "genetic testing [should be made] easily available to all who want it." Many, however, thought that genetic testing would lead to discrimination: 84 percent believed that health insurance companies would probably deny coverage on the basis of testing results, and 69 percent thought employers would probably turn down job applicants (VCU Center for Public Policy 2001).

[40] A recent study indicated that the public's lack of knowledge and indecisiveness and the way in which questions are worded are all factors in producing the mixed results in survey research on the subject of human embryonic stem cell research (Nisbet forthcoming).

"not much." College graduates were more likely than others to report exposure to information about stem cell research (Pew Research Center for the People and the Press 2002b).

In one survey, support for medical research that uses stem cells from human embryos declined from 48 percent in 2001 to 35 percent in 2002 and then increased to 47 percent in 2003. Opposition increased from 43 percent to 51 percent and then fell to 44 percent during the same period (VCU Center for Public Policy 2003). In another survey conducted in 2002, 43 percent of respondents said they supported Federal funding for stem cell research, down from 55 percent who gave that response in a Gallup poll conducted in 2001(Pew Research Center for the People and the Press 2002b). Support for Federal funding was somewhat higher (50 percent) and opposition lower (35 percent) among respondents who said they had heard at least a little about the issue.

A 2002 survey asked respondents what was more important: conducting research toward medical cures or not destroying human embryos (Pew Research Center for the People and the Press 2002b). Nearly half (47 percent) chose the former and 39 percent chose the latter.

In a more recent (2003) survey, 54 percent of respondents said that medical research using stem cells obtained from human embryos is morally acceptable, and 38 percent said it is morally wrong. These numbers were virtually unchanged from the previous year's survey (Gallup 2003). Public opinion on the morality of stem cell research tracks closely with views about abortion (VCU Center for Public Policy 2003).

Religious beliefs play a major role in shaping public opinion on various forms of medical research. For example, those who say that religion is important to them are more likely than others to oppose stem cell research and are less likely to think that the benefits of genetic research outweigh the risks. In 2001, 7 out of 10 survey respondents who said that religion was not important to them favored stem cell research, compared with 38 percent of those who said that religion provides a great deal of guidance for them (VCU Center for Public Policy 2001).

A 2002 survey also asked respondents what influenced their opinion on government funding of stem cell research (Pew Research Center for the People and the Press 2002b). Those who supported funding were most likely to cite media coverage[41] as the most important influence (42 percent), followed by their education (28 percent); religion was not a major factor. In contrast, opponents of funding were more likely to cite their religious beliefs (37 percent) than any other influence.

In the same 2002 survey, political conservatives and respondents with relatively little formal education were more likely than others to oppose stem cell research. Nearly two-thirds of college graduates agreed that the government should fund stem cell research; only one-fourth disagreed. Among respondents who had not completed high school, only one-third (35 percent) favored government funding for stem cell research, whereas nearly half (46 percent) were opposed (Pew Research Center for the People and the Press 2002b).

Scientists and medical researchers are Americans' most trusted source of information on stem cell research. More survey respondents said they had "a lot" of trust in this group than said they trusted specialists in medical ethics (28 percent), family and friends (15 percent), religious leaders (15 percent), President Bush (11 percent), the news media (5 percent), and members of Congress (4 percent) (VCU Center for Public Policy 2001).

Optimism About Curing Disease

Americans are more confident about the capacity of science and medicine to solve problems associated with disease than they are about society's capacity to address many other problems. Americans are more optimistic about reducing cancer mortality rates (in 2001, 71 percent of survey respondents expected the rate to decline by more than half) than they are about a variety of other challenges facing society, including improving voter turnout, reducing traffic accident fatalities, and cutting the crime rate. The only challenge that elicited greater confidence from respondents was teaching children to read by the time they reach the third grade: 75 percent thought that was possible (VCU Center for Public Policy 2001).

Environmental Issues

Concern about the quality of the environment declined after 2001, according to the Gallup Organization's Earth Day survey, conducted in March of each year. In 2003, 34 percent of those surveyed said they "worried a great deal" about the quality of the environment, down from 42 percent in 2001 (but about the same as 2002) (Saad 2003a).

Environment Compared With Other Concerns

Of the 11 problems asked about in the Earth Day survey, the quality of the environment ranked 9th in terms of "worry." More people said they worried a great deal about the availability and affordability of health care (55 percent), the possibility of future terrorist attacks in the United States (49 percent), crime and violence (45 percent), the economy (44 percent), drug use (42 percent), illegal immigration (37 percent), hunger and homelessness (37 percent), and unemployment (36 percent). Between 2001 and 2003, worry about the economy, illegal immigration, and unemployment increased, while worry about the other problems either declined or stayed the same (Saad 2003a).

Although the environment does not register with the public as a serious current problem, it is considered one of the most important problems the country will face in 25 years. But even by the long-term measure, concern about the environment has declined. Until 2002, the environment was the most frequently mentioned problem in response to the 25-year outlook question, more important than Medicare and Social Security, lack of energy sources, and the economy. However, in both 2002 and 2003, the economy topped the

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[41] Media coverage of stem cell research increased sharply between 2000 and 2001 and then fell steeply between 2001 and 2002 (Nisbet forthcoming).

list of long-term problems. In 2003, 14 percent of those surveyed named the economy (compared with 3 percent in 2001) and 9 percent named the environment (compared with 14 percent in 2001) (Saad 2003a).

Global Warming

In 2002, only 17 percent of Americans said they understood the issue of global warming "very well," about half (52 percent) understood it "fairly well," and the rest (about a third) answered either "not very well" or "not at all." There is a three-way split in public opinion on global warming as a problem, with approximately equal numbers of respondents saying it is a very serious problem, a moderate problem, and a slight problem (or not a problem at all) (Saad 2002).

Whatever their view about the seriousness of global warming, more than half (51 percent) of Americans think its effects have already begun, and others expect to see effects within a few years (6 percent) or within their lifetime (12 percent). Only 10 percent said the potential effects of global warming will never happen. In addition, most Americans (61 percent) believe that human activities are more responsible for increases in the Earth's temperature over the last century than natural causes, and most (62 percent) believe that news reports about the seriousness of global warming are either accurate or underestimate the problem. A third of those surveyed said that the media exaggerate the problem (Saad 2003b).

Although Americans seem to be aware of the issue and believe press reports, they are less concerned about global warming than other environmental hazards. On a list of 10 types of environmental issues, "damage to Earth's ozone layer" and the "'greenhouse effect' or global warming" ranked sixth and ninth, respectively, in 2002 (table 7-7). In addition, after increasing from 24 percent in 1997 to 40 percent in 2000, the number of people who worry a great deal about global warming declined to 29 percent in 2002. In fact, 9 of the 10 items on the list had similar declines between 2000 and 2002, with "maintenance of the nation's supply of fresh water for household needs" the only exception (Saad 2002).

Government Environmental Policy

Although half of Americans think the Federal Government needs to do more to protect the environment, satisfaction with the government's efforts has increased since the 1990s (Dunlap 2003). In 2003, 51 percent of survey respondents said the government was doing "too little" to protect the environment, down from 58 percent in 2000 and 68 percent in 1992. More than a third (37 percent) of respondents in 2003 said the government was doing "about the right amount," up from 30 percent in 2000 and 26 percent in 1992 (McComb 2003).

When survey respondents were asked to choose between two statements about tradeoffs between environmental protection and economic growth, "protection of the environment should be given priority, even at the risk of curbing economic growth" or "economic growth should be given priority, even if the environment suffers to some extent," more chose the former than the latter (47 versus 42 percent) in 2003. However, the percentage choosing the first statement has been declining steadily since 2000, reaching its all-time low (since the question was first asked nearly 20 years ago) in 2003; agreement with the second statement reached its all-time high in 2003 (figure 7-12) (Saad 2003a).

In 2003, most respondents (55 percent) opposed opening up the Alaskan Arctic Wildlife Refuge for oil exploration; 41 percent were in favor of it. About half (51 percent) opposed expanding the use of nuclear energy; 43 percent were in favor. These percentages have held fairly steady since 2001. In addition, between 70 and 80 percent of those surveyed in 2003 favored more stringent standards for auto emissions and business/industrial pollution, mandatory

Table 7-7
Environmental concerns of American public: 1997–2002
(Percent)

Issue	1997	1999	2000	2001	2002
Pollution of drinking water	NA	68	72	64	57
Pollution of rivers, lakes, and reservoirs	NA	61	66	58	53
Contamination of soil and water by toxic waste	NA	63	64	58	53
Maintenance of nation's supply of fresh water for household needs	NA	NA	42	35	50
Air pollution	42	52	59	48	45
Damage to Earth's ozone layer	33	44	49	47	38
Loss of tropical rain forests	NA	49	51	44	38
Extinction of plant and animal species	NA	NA	45	43	35
Greenhouse effect or global warming	24	34	40	33	29
Acid rain	NA	29	34	28	25

NA not available

NOTE: Percents reflect respondents who said they worry "a great deal" about the issue.

SOURCE: L. Saad, Poll analyses: Americans sharply divided on seriousness of global warming, Gallup Organization (Princeton, NJ, 2002).

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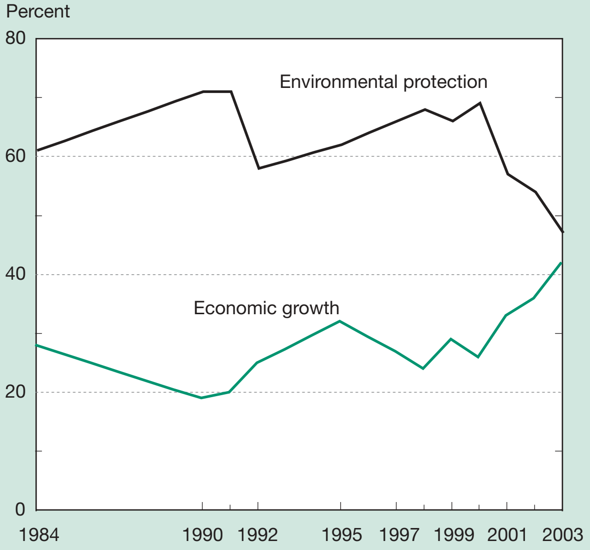
Figure 7-12
Public priorities for environmental protection vs. economic growth: 1984–2003



NOTE: Respondents were asked: “With which one of these statements about the environment and the economy do you most agree—protection of the environment should be given priority, even at the risk of curbing economic growth (or) economic growth should be given priority, even if the environment suffers to some extent?”

SOURCE: The Gallup Organization, Poll topics and trends: environment, 2003.

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controls on greenhouse gases, and stricter enforcement of environmental regulations (Dunlap 2003).

Technological Advances

Americans welcome new consumer products that are based on the latest technologies. Nowhere is that more obvious than in the burgeoning market for an array of devices that enhance and expand audio and visual communication capabilities.[42] At least two-thirds of the population now has a personal computer, and a similar percentage has a cell phone. In 2002, almost half (44 percent) said they owned a DVD player, up from 16 percent 2 years earlier. The number owning a Palm Pilot or a similar device more than doubled between 2000 and 2002, from 5 to 11 percent (Pew Research Center for the People and the Press 2002a). The number of households with cable or broadband access to the Internet has also been climbing rapidly (Cole 2002).

Most people believe that technology plays an important role in their lives. In a 2001 survey by ITEA, 59 percent disagreed with the statement “technology is a small factor in your everyday life.” Most people (62 percent) also thought that technology has had a greater effect on society than either the environment (20 percent) or the individual (17 percent). However, an overwhelming majority (94 percent) agreed that “the results of the use of technology can be good or bad” (Rose and Dugger 2002).

In the same survey, 75 percent of respondents wanted to know something about how technology works, compared with 24 percent who admitted not caring how it works as long as it works. Among respondents ages 18 to 29, 84 percent were interested in knowing how technology works.

In Europe, an overwhelming majority (95 percent) of those surveyed agreed that “technology is a major factor in the innovations developed within a country.” In addition, 84 percent of Europeans agreed that “science and technology play an important role in industrial development,” 64 percent agreed that “our economy can only become more competitive if we use the most advanced technologies,” and 56 percent agreed that “the Internet is essential for the development of new economic activities.” However, about half of those surveyed in Europe agreed that “scientific research does not make industrial products cheaper” and that “many high-tech products are only gadgets.”

Higher Education

Every other year, the American Council on Education commissions a survey to gauge the public’s perceptions of higher education. As in previous years, the 2003 survey revealed that most Americans recognize the benefits of higher education (Selingo 2003). Findings from the 2003 survey include the following:

- **Importance of a college degree.** About half (51 percent) of respondents agreed that a 4-year college degree is essential for success; 42 percent disagreed. Nearly half (46 percent) agreed that a graduate or professional degree will soon be more important than a 4-year degree; another 18 percent strongly agreed.
- **Value as a resource.** An overwhelming majority (91 percent) of those surveyed agreed that colleges and universities are one of America’s most valuable resources; 35 percent strongly agreed.
- **Government spending.** When asked about state and Federal Government investment in higher education, 67 percent of respondents said that governments should spend more, 10 percent said that governments spend too much, and 10 percent said that current spending is about right.
- **Public vs. private schools.** When asked to compare the quality of education at public and private universities, 41 percent of respondents thought education was better at private schools, 13 percent said the opposite, and 38 percent said the quality was about the same.
- **Workforce preparedness.** Although 56 percent of those surveyed agreed that college graduates today are well prepared for the workforce, only 4 percent strongly agreed; 34 percent disagreed, and an additional 5 percent strongly disagreed.

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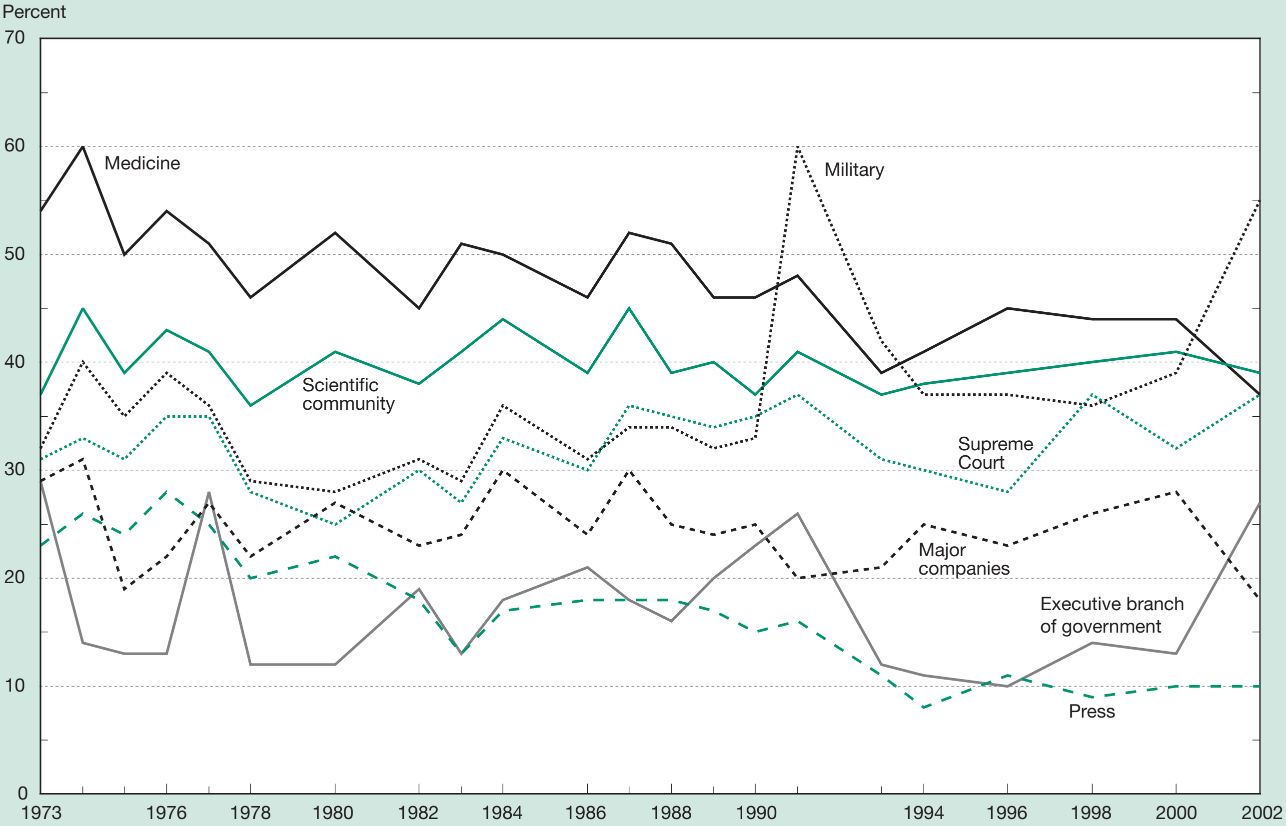
[42] A survey conducted in 2002 asked both Internet users and nonusers if communication technology has made the world a better or worse place. Sixty-six percent of Internet users and 54 percent of nonusers said it has made the world better; 6 percent of users and 17 percent of nonusers said it has made the world worse.

Figure 7-13
Public expressing confidence in leadership of selected institutions: 1973–2002



SOURCE: J. A. Davis, T. W. Smith, and P. V. Marsden, *General Social Survey 1972–2002 Cumulative Codebook* (University of Chicago, National Opinion Research Center). See appendix table 7-8.

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- **Research role.** More than half (56 percent) of respondents said that it is very important for colleges to conduct research that leads to discoveries about the world; 28 percent said it was important, and 14 percent said it was somewhat important.
- **Business development role.** Most respondents thought that colleges play at least a somewhat important role in fostering a healthy economy (i.e., conducting research that will make American businesses more competitive, helping to attract new businesses to local regions, and helping local businesses and industries be more successful); between 36 percent and 42 percent thought these roles were very important.

Confidence in Leadership of the Science Community

Public confidence in the leadership of various professional communities has been tracked for nearly 3 decades. Participants in the General Social Survey (GSS) are asked whether they have a “great deal of confidence, only some confidence, or hardly any confidence at all” in the leadership of various professional communities (Davis, Smith, and Marsden 2003). In 2002, 39 percent said they had a great deal of confidence in the leadership of the scientific community. This was the first time in the history of the survey that greater confidence was expressed in science than in medicine (figure 7-13 and appendix table 7-8).

Under normal circumstances, the science community would have claimed the top spot in the GSS in 2002. However, 55 percent of respondents said they had a great deal of confidence in the leadership of the military, up from 39 percent in 2000.[43] The events of September 11, 2001, and the subsequent war in Afghanistan may have contributed to the increase in public confidence in the military. A similar trend was seen in the early 1990s, when confidence in the military rose from 33 percent in 1990 to 60 percent in 1991 (at the time of the Gulf War); confidence in the military then dropped to 42 percent in 1993.

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[43] The U.S. military also topped the public confidence list in a poll conducted for the *Chronicle of Higher Education,* with 65 percent of those surveyed saying they had a great deal of confidence in the military. In that survey, 4-year colleges ranked second (51 percent), followed by the local police force (48 percent) and 4-year public-supported colleges and universities (46 percent). Other institutions mentioned in the survey included doctors (40 percent) and the presidency (33 percent).

Table 7-8
Prestige of various occupations: 1997–2002
(Percent)

Occupation	1997	1998	2000	2001	2002
Scientist	51	55	56	53	51
Doctor	52	61	61	61	50
Military officer	29	34	42	40	47
Teacher	49	53	53	54	47
Police officer	36	41	38	37	40
Priest/minister/clergyman	45	46	45	43	36
Engineer	32	34	32	36	34
Architect	NA	26	26	28	27
Member of Congress	23	25	33	24	27
Athlete	21	20	21	22	21
Entertainer	18	19	21	20	19
Journalist	15	15	16	18	19
Business executive	16	18	15	12	18
Lawyer	19	23	21	18	15
Banker	15	18	15	16	15
Union leader	14	16	16	17	14
Accountant	18	17	14	15	13

NA not available

NOTE: Percents are based on "very great prestige" responses to the following question: "I am going to read off a number of different occupations. For each, would you tell me if you feel it is an occupation of very great prestige, considerable prestige, some prestige, or hardly any prestige at all?"

SOURCE: The Harris Poll, survey conducted by Harris Interactive, August 15–19, 2002.

Science & Engineering Indicators – 2004

Other noteworthy changes in public confidence between 2000 and 2002 include:

◆ Declines of at least 7 percentage points in scores for the medical community (from 44 to 37 percent), banks and financial institutions (29 to 22 percent), major companies (28 to 18 percent), and organized religion (28 to 19 percent).

◆ An increase of 14 percentage points for the executive branch of the Federal Government, from 13 to 27 percent, which was the highest level in a quarter of a century. As with the military, the increase in the public's confidence in the executive branch may reflect the events of September 11, 2001.[44]

◆ An increase of 5 percentage points for the U.S. Supreme Court (32 to 37 percent).

The science community has ranked second or third in the GSS public confidence survey in every year since 1973. Although the vote of confidence for the science community has fluctuated somewhat over the years, it has remained around 40 percent. In contrast, although the medical profession has ranked first in most years, its vote of confidence, once as high as 60 percent (in 1974), has been gradually declining.

The public's confidence in the leadership of the press and television (10 percent for both) was the lowest of all institutions. These ratings have changed little in the past 10 years.

Science Occupations

Perceptions of science occupations can be assessed by examining the prestige that the public associates with them. Respondents to an August 2002 Harris poll ranked "scientist" first among 17 occupations in terms of prestige, the first time the top spot did not go to "doctor" (table 7-8).[45] The engineering profession ranked seventh, the same as in 2001 but up one spot from 2000 (Taylor 2002a).

Although the public accorded less prestige to engineers than to scientists, doctors, military officers, teachers, police officers, and the clergy, engineers did command more respect than 10 other occupations."[46]

The public's perception of science occupations can be measured in other ways. When asked how they would feel if their son or daughter wanted to become a scientist, 80 percent of respondents to the 2001 NSF survey said they would be happy with that decision (18 percent said they would not care and 2 percent said they would be unhappy). Responses were the same for both sons and daughters.

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[44] Within weeks of September 11, the number of people who said they trusted the government to do what is right most of the time hit its highest levels in 30 years, rising to 55 percent in one *New York Times*/CBS News poll (Stille 2002). (As recently as 1998, the figure was as low as 26 percent.)

[45] The question asked was: "I am going to read off a number of different occupations. For each, would you tell me if you feel it is an occupation of very great prestige, considerable prestige, some prestige, or hardly any prestige at all?" The rankings are based on the "very great prestige" responses.

[46] However, in a 2000 Gallup survey that asked the public about standards of honesty and ethics in 32 professions, engineers ranked 9th (Carlson 2000). In a November 2002 Harris poll (Taylor 2002b), scientists ranked fifth out of 21 occupations (after teachers, doctors, professors, and police officers, and just ahead of the President and judges) in response to the question "Would you generally trust each of the following types of people to tell the truth, or not?"

The 2001 Eurobarometer survey found that the three professions held in highest esteem by the European public all had a scientific or technical dimension: doctors (71 percent), scientists (45 percent), and engineers (30 percent). Rankings were similar in 1992 (except that engineers ranked fourth, after judges). Scientists were most likely to be rated highly in Sweden (55 percent), Greece (53 percent), and Denmark (50 percent). In addition, when asked who they would trust to explain the reasons for a local disaster, Europeans were more likely to name scientists than any other group.

An overwhelming majority of surveyed Europeans (96 percent) thought it was important for their country to encourage more young people to enter careers in S&T. Asked why more young people were not choosing scientific studies and careers, more than half of survey respondents agreed that lack of appeal, lack of interest, and difficulty were factors; about a third cited the poor image of science in society.

Seventy-one percent of surveyed Europeans thought more should be done to encourage girls and young women to pursue scientific studies and careers, and 67 percent agreed that "there ought to be more women in European scientific research." Sixty-three percent thought that the European Union should be more open to foreign scientists, and 58 percent agreed that the best scientists leave Europe for the United States.

Conclusion

Most Americans recognize and appreciate the benefits of S&T. The public is also highly supportive of the government's role in funding basic research. By most measures, American attitudes about S&T are considerably more positive than attitudes in Europe.

In both the United States and Europe, however, residents do not know much about S&T. The percentage of correct responses to a battery of questions designed to assess the level of knowledge and understanding of scientific terms and concepts has not changed appreciably in the past few years. In addition, approximately 70 percent of Americans do not understand the scientific process, technological literacy is weak, and belief in pseudoscience is relatively widespread and may be growing.

Although Americans generally have very positive attitudes about S&T and high regard for the science community, some harbor reservations about S&T, and 70 percent believe that scientific research does not pay enough attention to moral values. Although Americans are overwhelmingly opposed to human cloning, they are more evenly divided about stem cell research.

Americans continue to get most of their information about the latest developments in S&T from watching television. However, the Internet has made inroads and is now the leading source of information on specific scientific issues.

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Chapter Overview

In response to increasing interest in both the policy and research communities about the role of science and technology (S&T) in state and regional economic development, a new experimental chapter devoted to the subject is included in the 2004 edition of *Science and Engineering Indicators.* This chapter focuses on the performance of individual states, the District of Columbia, and Puerto Rico. It introduces a series of indicators designed to present information about various aspects of the state S&T infrastructure and to stimulate discussion about appropriate state S&T indicators. The data used to calculate these indicators have been gathered from both public and private sources. Whenever possible, data covering a 10-year span are provided to identify meaningful trends. However, because consistent data were not always available for the 10-year period, data for certain indicators are given only for the years in which comparisons are justified.

Ready access to accurate and timely state-level information is an important tool for formulating effective S&T policies below the national level. By studying the programs and performance of their peers, state policymakers may be able to assess and enhance their own programs and performance. Hopefully, these indicators will encourage the development of benchmarks that individual states can use to assess their progress in specific areas and to assist in setting realistic goals for improvement. The tables are intended to give the user a convenient listing of some of the quantitative data that may be relevant to technology-based economic development. In addition to describing the behavior of an indicator, the “Findings” section frequently presents an interpretation of the behavior’s relevance and meaning. The interpretation is sometimes speculative, with the objective of motivating further thought and discussion.

Types of Indicators

Twenty-four indicators are included in this chapter and grouped into the following areas:

- Secondary education
- Higher education
- Workforce
- Financial research and development inputs
- R&D outputs
- S&T in the economy

Indicators in the first two areas address educational attainment in a particular state. They focus on student science and mathematics skills at the secondary level, public school teacher salaries, and undergraduate and graduate degrees in S&E.

The workforce indicators focus on the level of S&E training in the employed labor force. These indicators reflect the higher education level of the labor force and the degree of specialization in S&E disciplines and occupations.

Indicators in the financial section address the source and level of funding for R&D. They show how much R&D is being performed relative to the size of a state’s business base. Comparison of these indicators illustrates the extent to which R&D is conducted by industrial or academic performers.

The last two sections, R&D and S&T outputs, quantify the robustness of a region’s S&T activity through measurement of its production of patents and technical publications, venture capital investment, and high-technology business activity. Although data adequately addressing both the quantity and quality of R&D results are difficult to find, these indicators offer a reasonable information base.

Data Sources and Considerations

Raw data for each indicator are presented in the tables. The first entry in each table represents the average value for the states. For most indicators, the state average was calculated by summing the values for the 50 states and the District of Columbia for both the numerator and the denominator and then dividing the two. Any alternate approach is indicated in the notes at the bottom of the table.

The values for most indicators are expressed as ratios or percentages to remove the effect of state size and facilitate comparison between large and small states or between heavily and sparsely populated states. For example, an indicator of higher education achievement is not defined as the absolute number of degrees conferred in a state, because sparsely populated states are not likely to have as extensive a higher education system as states with larger populations. Instead, the indicator is defined as the number of degrees per number of residents in the college-age cohort, which measures the intensity of educational services relative to the size of the resident population.

No official list of high-technology industries or sanctioned methodology to identify the most technology-intensive industries exists in the United States. The definition used here was developed by the Department of Commerce’s Technology Administration in concert with the U.S. Department of Labor’s Bureau of Labor Statistics. See “Technical Note: Defining High-Technology Industries.”

Indicator Pages

A page containing key elements has been created to supplement the data for each indicator. The first element is a map that is color coded to show in which quartile each state placed on that indicator for the latest year that data were available. This helps the reader quickly grasp geographic trends. See the sample map below showing the outline of each state. On the map, the darkest color indicates states ranking in the first or highest quartile, and white indicates states ranking in the fourth or lowest quartile. Cross-hatching indicates states for which no data are available.

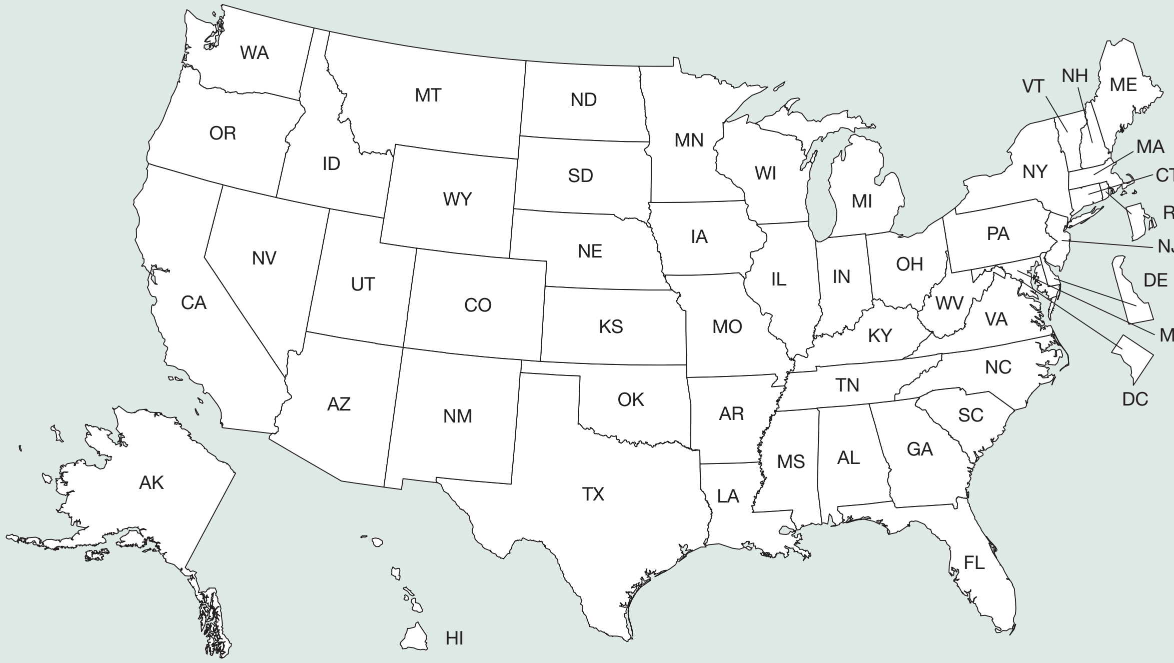
The second element is a quartiles table. States falling in a particular quartile are listed alphabetically. The range of indicator values for that quartile is shown at the top of the column. Ties at quartile breaks were resolved by moving the tied states into one quartile. All of the indicators are broad measures, and several rely on sample estimates that have a margin of error. Small differences in state values generally carry little useful information.

The third element, on the lower left side of the page, is a short description of the indicator, a brief note about the nature of the data, and other information describing the data.

The fourth element, on the lower right side of the page within a shaded box, is a summary of findings. The findings include the national average and comments on trends and patterns for the particular indicator.

The final element, appearing at the bottom of each page, is a short citation for the data source. The full citation appears on the facing page.

U.S. Map and List of Abbreviations



AK........ Alaska
AL........ Alabama
AR........ Arkansas
AZ........ Arizona
CA........ California
CO....... Colorado
CT........ Connecticut
DC....... District of Columbia
DE........ Delaware
FL........ Florida
GA....... Georgia

HI.........Hawaii
IA.........Iowa
ID.........Idaho
IL..........Illinois
IN.........Indiana
KS........Kansas
KY........Kentucky
LA........Louisiana
MA.......Massachusetts
MD.......Maryland

ME........Maine
MI.........Michigan
MN........Minnesota
MO.......Missouri
MS........Mississippi
MT........Montana
NC........North Carolina
ND........North Dakota
NE........Nebraska
NH........New Hampshire

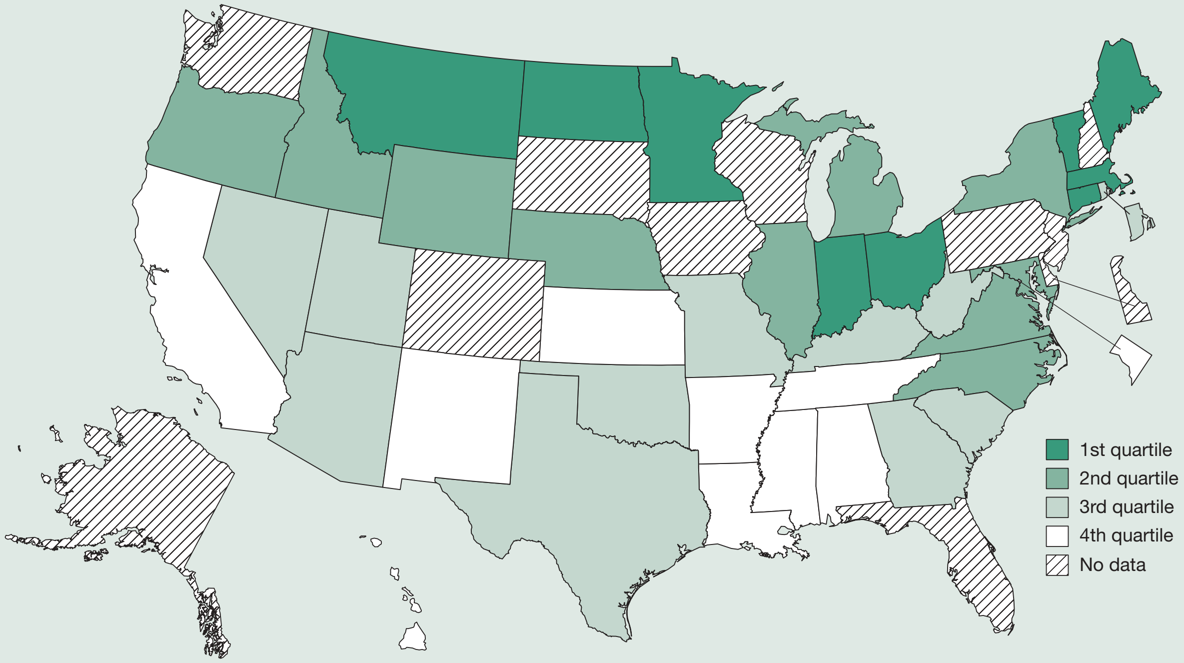
NJ........New Jersey
NM.......New Mexico
NV........Nevada
NY........New York
OH........Ohio
OK........Oklahoma
OR........Oregon
PA.........Pennsylvania
RI..........Rhode Island
SC........South Carolina

SD........South Dakota
TN........Tennessee
TX.........Texas
UT........Utah
VA.........Virginia
VT.........Vermont
WA........Washington
WI.........Wisconsin
WV........West Virginia
WY.......Wyoming

Eighth Grade Mathematics Performance

Figure 8-1

Quartile groups for eighth grade mathematics performance: 2000



1st quartile (288–282)	2nd quartile (281–276)	3rd quartile (275–266)	4th quartile (263–254)	No data
Connecticut	Idaho	Arizona	Alabama	Alaska
Indiana	Illinois	Georgia	Arkansas	Colorado
Kansas	Maryland	Kentucky	California	Delaware
Maine	Michigan	Missouri	District of Columbia	Florida
Massachusetts	Nebraska	Nevada	Hawaii	Iowa
Minnesota	New York	Oklahoma	Louisiana	New Hampshire
Montana	North Carolina	Rhode Island	Mississippi	New Jersey
North Dakota	Oregon	South Carolina	New Mexico	Pennsylvania
Ohio	Virginia	Texas	Tennessee	South Dakota
Vermont	Wyoming	Utah		Washington
		West Virginia		Wisconsin

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress. See table 8-1.

Understanding mathematics is an important life skill and a prerequisite to further study in science or engineering. This indicator measures the knowledge of a state's eighth grade public school students in mathematics.

The National Assessment of Educational Progress (NAEP) is a federally authorized ongoing assessment of student performance in various subjects on a national scale. States participate at their option; no data means the state did not participate. The mathematics assessment is based on the *NAEP Mathematics Framework,* developed through a national consensus process. Questions cover five areas: number sense, properties, and operations; measurement; geometry and spatial sense; data analysis, statistics, and probability; and algebra and functions.

The 2000 NAEP for mathematics was administered to 4th, 8th, and 12th grade students in 1990, 1992, 1996, and 2000. The 2000 national 8th grade public school sample comprised 9,389 students from 385 public schools. Although the size of individual state samples may vary, samples included about 2,500 8th graders from 100 public schools in each state.

Student performance is described in terms of average scores on a 0–500 scale and achievement levels: basic, proficient, and advanced. The basic level (262–298) denotes partial mastery of the knowledge and skills that are fundamental for proficient work in mathematics at the eighth grade level. The proficient level (299–332) represents solid academic performance and demonstrates that the student is competent in handling challenging mathematical subject matter. The advanced level (333–500) signifies superior performance in mathematics at the eighth grade level.

Findings

- Nationwide, eighth graders in public schools showed progress throughout the decade, with a higher average score in 2000 (274) than in 1990 (263) and 1992 (267).
- In 2000, the nationwide percentage of eighth grade public school students performing at or above the proficient level—identified by the National Assessment Governing Board as the level that all students should reach—was 27 percent.
- All but five of the participating states had averages in the basic achievement level, indicating partial mastery; none reached a proficient or superior average.

Table 8-1

Eighth grade mathematics performance, by state: 1992, 1996, and 2000

(Score)

State	1992	1996	2000
National average	267	271	274
Alabama	252	257	262
Alaska	NA	278	NA
Arizona	265	268	271
Arkansas	256	262	261
California	261	263	262
Colorado	272	276	NA
Connecticut	274	280	282
Delaware	263	267	NA
District of Columbia	235	233	234
Florida	260	264	NA
Georgia	259	262	266
Hawaii	257	262	263
Idaho	NA	NA	278
Illinois	NA	NA	277
Indiana	270	276	283
Iowa	283	284	NA
Kansas	NA	NA	284
Kentucky	262	267	272
Louisiana	250	252	259
Maine	279	284	284
Maryland	265	270	276
Massachusetts	273	278	283
Michigan	267	277	278
Minnesota	282	284	288
Mississippi	246	250	254
Missouri	271	273	274
Montana	NA	283	287
Nebraska	278	283	281
Nevada	NA	NA	268
New Hampshire	NA	NA	NA
New Jersey	NA	NA	NA
New Mexico	260	262	260
New York	266	270	276
North Carolina	258	268	280
North Dakota	283	284	283
Ohio	NA	NA	283
Oklahoma	NA	NA	272
Oregon	NA	276	281
Pennsylvania	NA	NA	NA
Rhode Island	266	269	273
South Carolina	261	261	266
South Dakota	NA	NA	NA
Tennessee	259	263	263
Texas	265	270	275
Utah	274	277	275
Vermont	NA	279	283
Virginia	268	270	277
Washington	NA	276	NA
West Virginia	259	265	271
Wisconsin	278	283	NA
Wyoming	275	275	277
Puerto Rico	NA	NA	NA

NA not available

NOTES: The national average for each year is the reported value for the nation found in the National Assessment of Educational Progress (NAEP) reports. NAEP grade 8 mathematics scores are for public schools only. In 1992, Alaska, Montana, Oregon, Vermont, and Washington did not participate in NAEP. In 1996, Alaska, Arkansas, Iowa, Maryland, Michigan, Montana, New York, South Carolina, Vermont, and Wisconsin did not satisfy one or more school participation rate guidelines for the school sample(s). In 2000, Arizona, California, Idaho, Illinois, Indiana, Kansas, Maine, Michigan, Minnesota, Montana, New York, Oregon, and Vermont did not satisfy one or more school participation rate guidelines for the school sample(s).

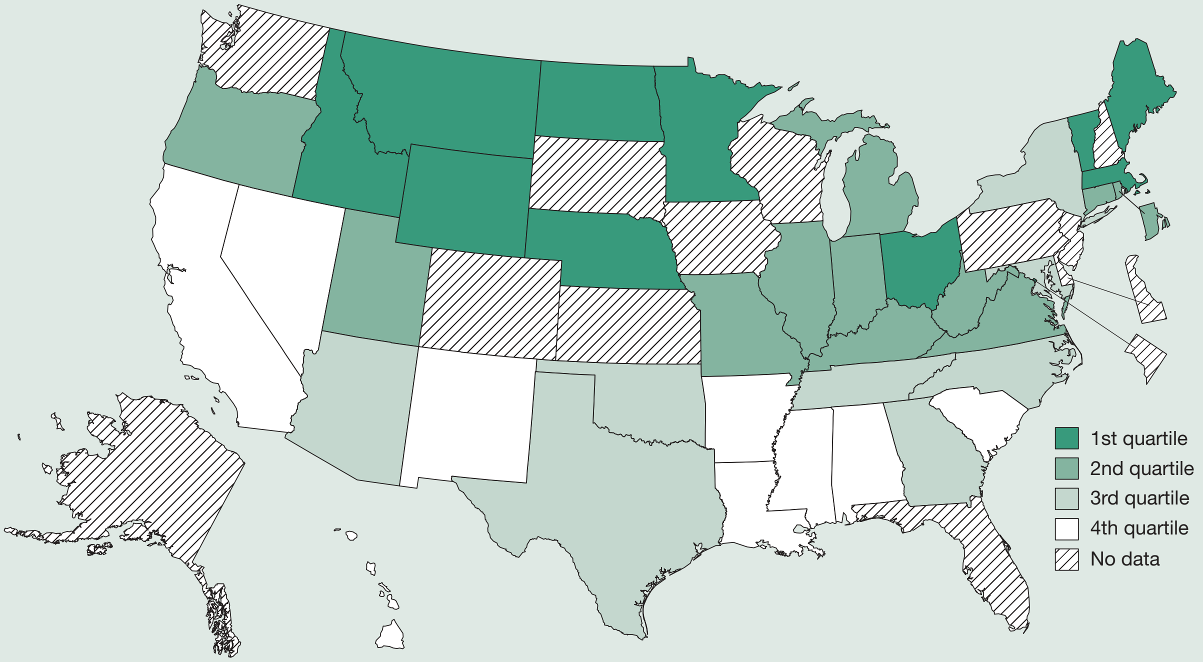
SOURCE: U.S. Department of Education, National Center for Education Statistics, NAEP, various years.

Science & Engineering Indicators – 2004

Eighth Grade Science Performance

Figure 8-2

Quartile groups for eighth grade science performance: 2000



1st quartile (165–157)	2nd quartile (156–150)	3rd quartile (149–144)	4th quartile (143–132)	No data
Idaho	Connecticut	Arizona	Alabama	Alaska
Maine	Illinois	Georgia	Arkansas	Colorado
Massachusetts	Indiana	Maryland	California	Delaware
Minnesota	Kentucky	New York	Hawaii	District of Columbia
Montana	Michigan	North Carolina	Louisiana	Florida
Nebraska	Missouri	Oklahoma	Mississippi	Iowa
North Dakota	Oregon	Tennessee	Nevada	Kansas
Ohio	Rhode Island	Texas	New Mexico	New Hampshire
Vermont	Utah		South Carolina	New Jersey
Wyoming	Virginia			Pennsylvania
	West Virginia			South Dakota
				Washington
				Wisconsin

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress. See table 8-2.

Understanding fundamentals of science is important in modern society and a prerequisite to further study in science or engineering. This indicator measures the knowledge of a state's eighth grade public school students in science.

The National Assessment of Educational Progress (NAEP) is a federally authorized ongoing assessment of student achievement. States participate at their option; no data means the state did not participate. The assessment is based on the *NAEP Science Framework,* developed through a national consensus process. Questions cover three content areas—earth, physical, and life sciences—including students' conceptual understanding, scientific investigation, and practical reasoning.

The NAEP for science was administered in 1996 and 2000 to representative samples of 4th, 8th, and 12th graders. The 2000 sample comprised 9,443 8th graders from 385 public schools. Although the size of state samples may vary, they included about 2,500 students from 100 schools in each state.

Student performance is described in terms of average scores on a 0–300 scale and achievement levels: basic, proficient, and advanced.

The basic level (143–169) denotes partial mastery of the knowledge and skills fundamental for proficient work at the eighth grade level. The proficient level (170–207) represents solid academic performance. Students reaching this level are competent with challenging subject matter, including knowledge, application of such knowledge to real-world situations, and appropriate analytical skills. The advanced level (208–300) signifies superior performance.

Findings

- Nationwide, eighth graders scored similarly in 1996 (148) and 2000 (149).
- In 2000, the nationwide percentage of eighth grade students performing at or above the proficient level—identified by the National Assessment Governing Board as the level that all students should reach—was 32 percent.
- All but seven of the participating states had averages in the basic achievement level, indicating partial mastery; none reached a proficient or superior average.

Table 8-2

Eighth grade science performance, by state: 1996 and 2000

(Score)

State	1996	2000
National average	148	149
Alabama	139	141
Alaska	153	NA
Arizona	145	146
Arkansas	144	143
California	138	132
Colorado	155	NA
Connecticut	155	154
Delaware	142	NA
District of Columbia	113	NA
Florida	142	NA
Georgia	142	144
Hawaii	135	132
Idaho	NA	159
Illinois	NA	150
Indiana	153	156
Iowa	158	NA
Kansas	NA	NA
Kentucky	147	152
Louisiana	132	136
Maine	163	160
Maryland	145	149
Massachusetts	157	161
Michigan	153	156
Minnesota	159	160
Mississippi	133	134
Missouri	151	156
Montana	162	165
Nebraska	157	157
Nevada	NA	143
New Hampshire	NA	NA
New Jersey	NA	NA
New Mexico	141	140
New York	146	149
North Carolina	147	147
North Dakota	162	161
Ohio	NA	161
Oklahoma	NA	149
Oregon	155	154
Pennsylvania	NA	NA
Rhode Island	149	150
South Carolina	139	142
South Dakota	NA	NA
Tennessee	143	146
Texas	145	144
Utah	156	155
Vermont	157	161
Virginia	149	152
Washington	150	NA
West Virginia	147	150
Wisconsin	160	NA
Wyoming	158	158
Puerto Rico	NA	NA

NA not available

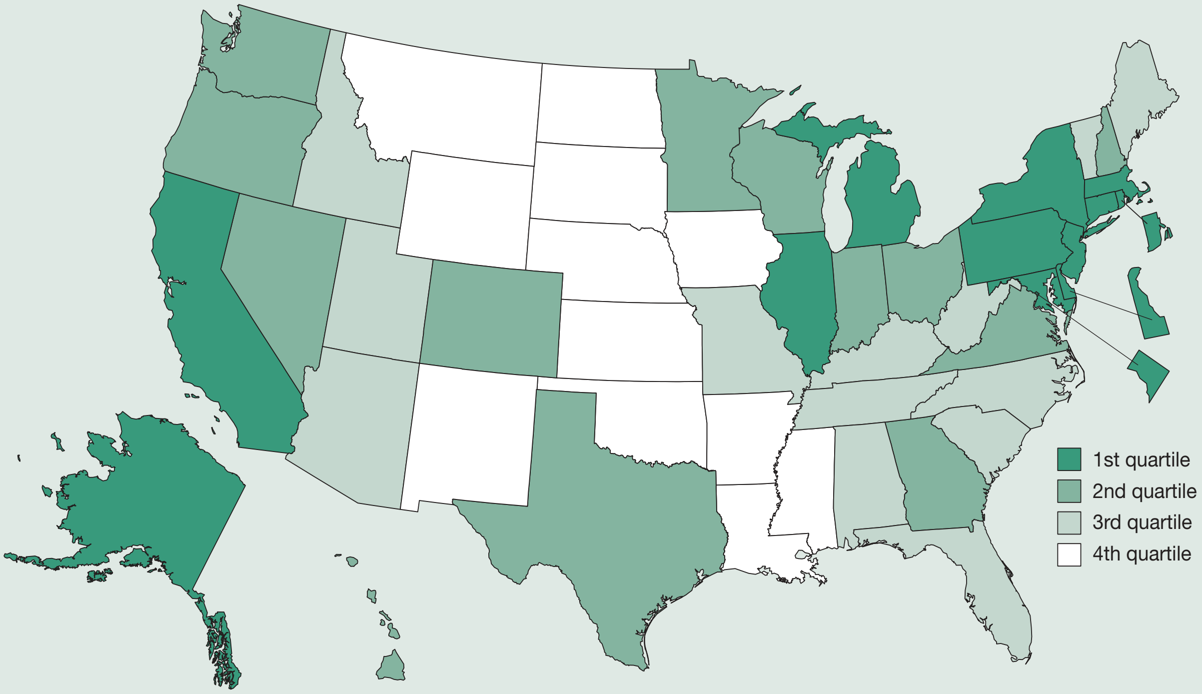
NOTES: The national average for each year is the reported value for the nation found in the National Assessment of Educational Progress (NAEP) reports. NAEP grade 8 science scores are for public schools only. In 1996, Alaska, Arkansas, Iowa, Maryland, Michigan, Montana, New York, South Carolina, Vermont, and Wisconsin did not satisfy one or more school participation rate guidelines for the school sample(s). In 2000, Arizona, California, Idaho, Illinois, Indiana, Maine, Michigan, Minnesota, Montana, New York, Oregon, Vermont, and Wisconsin did not satisfy one or more school participation rate guidelines for the school sample(s).

SOURCE: U.S. Department of Education, National Center for Education Statistics, NAEP, various years.

Science & Engineering Indicators – 2004

Public School Teacher Salaries

Figure 8-3
Quartile groups for public school teacher salaries: 2000



1st quartile ($51,160–42,111)	2nd quartile ($40,809–36,379)	3rd quartile ($36,004–32,872)	4th quartile ($32,126–27,345)
Alaska	Colorado	Alabama	Arkansas
California	Georgia	Arizona	Iowa
Connecticut	Hawaii	Florida	Kansas
Delaware	Indiana	Idaho	Louisiana
District of Columbia	Minnesota	Kentucky	Mississippi
Illinois	Nevada	Maine	Montana
Maryland	New Hampshire	Missouri	Nebraska
Massachusetts	Ohio	North Carolina	New Mexico
Michigan	Oregon	South Carolina	North Dakota
New Jersey	Texas	Tennessee	Oklahoma
New York	Virginia	Utah	South Dakota
Pennsylvania	Washington	Vermont	Wyoming
Rhode Island	Wisconsin	West Virginia	

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000. See table 8-3.

This indicator measures the income public school teachers receive from their work. Relatively low teacher salaries are said to hinder recruitment into the teaching profession.

Public school teacher salaries may reflect a range of factors, including the value placed on primary and secondary education, a state’s cost of living, the experience and educational attainment of the teachers, and local supply and demand in the job market. The average salary is the average of the base salary of full-time public school teachers during the 1999–2000 school year. It includes recent college graduates and seasoned veterans. Educational credentials may encompass provisional certification through bachelor’s, master’s, or doctoral degrees.

Findings

- Salaries for public school teachers nationwide averaged $39,893 in 2000 and among states ranged from a high of more than $51,000 to a low of $27,000.
- Seventeen states and the District of Columbia had average salaries higher than the national average, and 33 states had lower average salaries.
- The median salary was $36,379. High salaries for public school teachers do not necessarily correspond to high average student achievement scores on the NAEP mathematics and science tests.

Table 8-3
Public school teacher salaries, by state: 2000

State	Average salary
National average	39,893
Alabama	34,818
Alaska	45,665
Arizona	33,924
Arkansas	31,300
California	45,111
Colorado	37,012
Connecticut	50,170
Delaware	42,732
District of Columbia	46,634
Florida	35,819
Georgia	38,504
Hawaii	38,217
Idaho	34,416
Illinois	42,152
Indiana	40,809
Iowa	31,953
Kansas	32,126
Kentucky	34,478
Louisiana	29,811
Maine	36,004
Maryland	42,111
Massachusetts	45,079
Michigan	47,615
Minnesota	40,372
Mississippi	30,592
Missouri	32,872
Montana	30,271
Nebraska	29,114
Nevada	38,514
New Hampshire	37,563
New Jersey	51,036
New Mexico	32,055
New York	51,160
North Carolina	33,375
North Dakota	27,345
Ohio	39,348
Oklahoma	29,017
Oregon	40,302
Pennsylvania	46,917
Rhode Island	46,504
South Carolina	34,273
South Dakota	27,488
Tennessee	33,312
Texas	36,379
Utah	34,008
Vermont	35,480
Virginia	36,888
Washington	40,200
West Virginia	34,260
Wisconsin	39,969
Wyoming	31,501
Puerto Rico	NA

NA not available

NOTE: Public school teacher salaries are the average of the base salaries of full-time public school teachers.

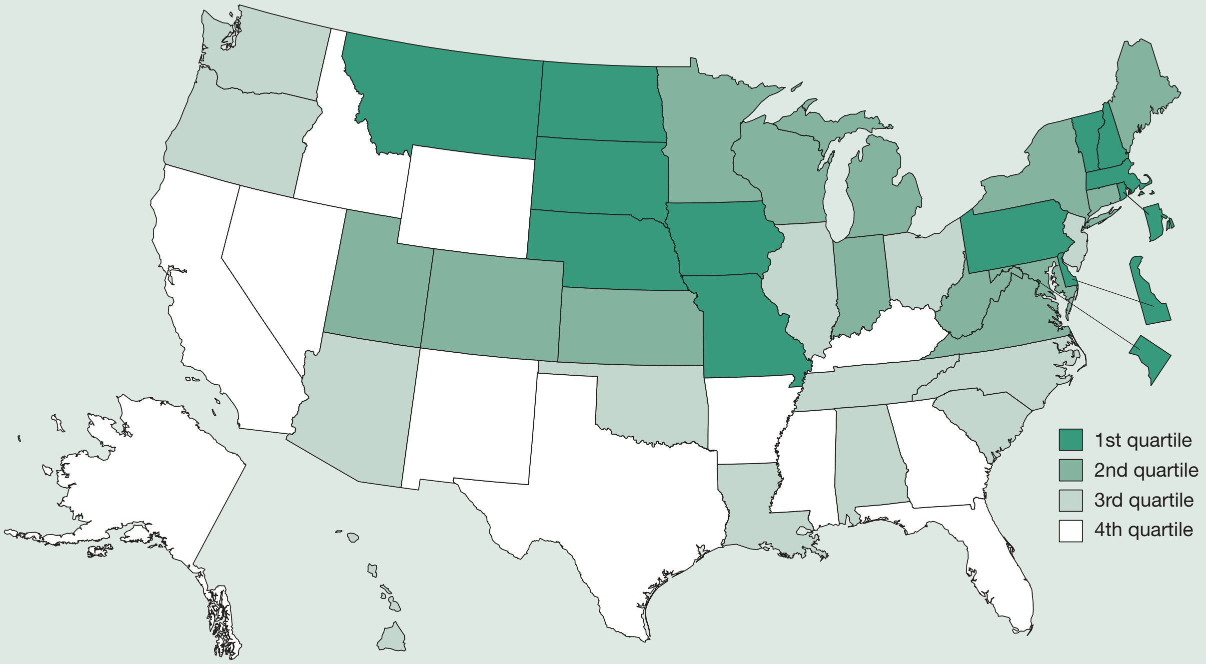
SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

Science & Engineering Indicators – 2004

Bachelor's Degrees Conferred per 1,000 18–24-Year-Olds

Figure 8-4

Quartile groups for bachelor's degrees conferred per 1,000 18–24-year-olds: 2000



1st quartile (104.5–55.9)	2nd quartile (55.6–48.4)	3rd quartile (48.4–39.8)	4th quartile (38.9–22.6)
Delaware	Colorado	Alabama	Alaska
District of Columbia	Connecticut	Arizona	Arkansas
Iowa	Indiana	Hawaii	California
Massachusetts	Kansas	Illinois	Florida
Missouri	Maine	Louisiana	Georgia
Montana	Maryland	New Jersey	Idaho
Nebraska	Michigan	North Carolina	Kentucky
New Hampshire	Minnesota	Ohio	Mississippi
North Dakota	New York	Oklahoma	Nevada
Pennsylvania	Utah	Oregon	New Mexico
Rhode Island	Virginia	South Carolina	Texas
South Dakota	West Virginia	Tennessee	Wyoming
Vermont	Wisconsin	Washington	

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System; and U.S. Bureau of the Census, Population Division. See table 8-4.

Earning a bachelor's degree gives people a greater opportunity to work in higher paying jobs than is generally available to people with less education; it also prepares them for advanced education. The ratio of bachelor's degrees awarded to a state's 18–24-year-old population is a broad measure of a state's relative success in producing degrees at this level. The 18–24-year-old cohort was chosen to approximate the age range of most people pursuing an undergraduate degree.

A high value of this indicator may suggest the successful provision of educational opportunity at this level. The value may also be high when a higher education system draws many out-of-state students, which may particularly affect the results for some sparsely populated states and the District of Columbia.

Findings

- In 2000, 1.24 million bachelor's degrees were conferred in all fields, up from 1.05 million in 1990.
- This increase across the United States in 2000 translates to about 46 bachelor's degrees per 1,000 18–24-year-olds, ranging from about 23 to 85 across states; the District of Columbia exceeded 104 (an outlier reflecting special characteristics).
- Over the decade, the number of bachelor's degrees awarded in the United States increased relative to the 18–24-year-old population, rising from 39 in 1990 to 46 by mid-decade, similar to the 2000 level.
- The pattern for states in the top two quartiles is similar to those for mathematics and science performance of eighth graders.

Table 8-4

Bachelor's degrees conferred per 1,000 18–24-year-olds, by state: 1990, 1995, and 2000

State	Bachelor's degrees			18–24-year-old population			Bachelor's degrees per 1,000 18–24-year-olds		
	1990	1995	2000	1990	1995	2000	1990	1995	2000
All states	1,049,656	1,160,126	1,236,378	26,737,766	25,112,313	27,143,454	39.3	46.2	45.5
Alabama	17,059	19,924	21,185	443,335	444,704	439,612	38.5	44.8	48.2
Alaska	1,043	1,526	1,364	55,847	62,426	57,292	18.7	24.4	23.8
Arizona	14,172	18,533	24,867	392,680	413,693	514,101	36.1	44.8	48.4
Arkansas	7,475	8,623	9,405	237,056	248,435	261,738	31.5	34.7	35.9
California	98,069	108,215	116,648	3,412,257	3,013,123	3,366,030	28.7	35.9	34.7
Colorado	17,344	20,226	21,771	335,525	351,400	430,111	51.7	57.6	50.6
Connecticut	14,333	14,158	14,546	345,433	270,474	271,585	41.5	52.3	53.6
Delaware	3,462	4,421	4,616	76,233	67,051	75,328	45.4	65.9	61.3
District of Columbia	7,449	7,661	7,589	82,558	51,875	72,637	90.2	147.7	104.5
Florida	35,493	44,916	50,476	1,215,657	1,170,757	1,330,602	29.2	38.4	37.9
Georgia	21,402	26,312	28,947	738,584	730,927	837,732	29.0	36.0	34.6
Hawaii	3,720	4,500	4,993	121,185	115,821	114,893	30.7	38.9	43.5
Idaho	3,169	4,235	4,711	98,247	126,435	138,829	32.3	33.5	33.9
Illinois	49,757	52,436	55,330	1,212,950	1,127,699	1,210,898	41.0	46.5	45.7
Indiana	27,625	30,253	31,936	604,882	582,508	614,721	45.7	51.9	52.0
Iowa	16,129	17,421	18,675	283,713	273,088	298,008	56.8	63.8	62.7
Kansas	12,521	14,835	14,681	254,493	251,111	275,592	49.2	59.1	53.3
Kentucky	12,225	14,570	15,643	399,989	401,248	401,858	30.6	36.3	38.9
Louisiana	15,905	17,920	19,693	464,511	460,667	473,801	34.2	38.9	41.6
Maine	4,944	5,893	5,672	123,772	112,864	103,903	39.9	52.2	54.6
Maryland	19,502	20,824	21,887	505,373	432,516	450,922	38.6	48.1	48.5
Massachusetts	43,559	40,279	42,308	709,099	538,602	579,328	61.4	74.8	73.0
Michigan	42,428	44,317	45,407	1,004,527	935,335	932,137	42.2	47.4	48.7
Minnesota	22,851	23,872	23,129	442,809	417,482	470,434	51.6	57.2	49.2
Mississippi	8,808	10,335	10,982	293,346	303,426	310,974	30.0	34.1	35.3
Missouri	24,612	27,918	29,964	517,191	499,397	535,978	47.6	55.9	55.9
Montana	3,862	4,354	5,071	70,011	83,675	85,757	55.2	52.0	59.1
Nebraska	8,677	10,105	10,755	155,887	160,166	174,425	55.7	63.1	61.7
Nevada	2,235	3,365	4,070	118,945	128,251	179,708	18.8	26.2	22.6
New Hampshire	6,745	7,395	7,776	117,602	96,548	103,369	57.4	76.6	75.2
New Jersey	22,859	24,627	26,939	779,184	678,491	676,628	29.3	36.3	39.8
New Mexico	5,010	6,032	6,215	151,824	167,305	177,576	33.0	36.1	35.0
New York	90,195	94,762	98,220	1,953,424	1,649,416	1,765,453	46.2	57.5	55.6
North Carolina	27,288	32,321	35,257	781,053	716,816	806,821	34.9	45.1	43.7
North Dakota	4,202	4,440	4,877	67,853	66,177	73,118	61.9	67.1	66.7
Ohio	47,144	49,755	49,973	1,136,418	1,070,668	1,056,544	41.5	46.5	47.3
Oklahoma	13,601	15,307	15,573	321,389	328,996	357,085	42.3	46.5	43.6
Oregon	12,586	12,917	14,074	267,528	282,990	327,884	47.0	45.6	42.9
Pennsylvania	60,572	63,072	66,344	1,226,775	1,074,942	1,094,449	49.4	58.7	60.6
Rhode Island	8,789	9,094	8,594	120,358	90,614	106,607	73.0	100.4	80.6
South Carolina	13,215	15,060	16,523	406,526	389,480	407,851	32.5	38.7	40.5
South Dakota	3,760	4,412	4,760	68,113	72,599	77,634	55.2	60.8	61.3
Tennessee	17,577	20,463	22,815	527,655	516,027	548,856	33.3	39.7	41.6
Texas	60,472	70,048	75,830	1,890,844	1,943,360	2,198,881	32.0	36.0	34.5
Utah	10,907	14,262	16,797	199,986	253,174	317,431	54.5	56.3	52.9
Vermont	4,517	4,591	4,810	63,166	54,240	56,586	71.5	84.6	85.0
Virginia	27,119	30,472	32,905	719,731	659,229	679,398	37.7	46.2	48.4
Washington	18,320	21,773	23,920	488,539	500,401	559,361	37.5	43.5	42.8
West Virginia	7,414	8,656	8,545	179,991	189,426	172,431	41.2	45.7	49.6
Wisconsin	25,888	26,943	27,513	512,326	485,889	520,629	50.5	55.5	52.8
Wyoming	1,646	1,777	1,797	41,386	50,369	49,928	39.8	35.3	36.0
Puerto Rico	12,173	13,820	16,164	NA	NA	428,894	NA	NA	37.7

NA not available

NOTE: The state total for each year is the sum of the 50 states and the District of Columbia.

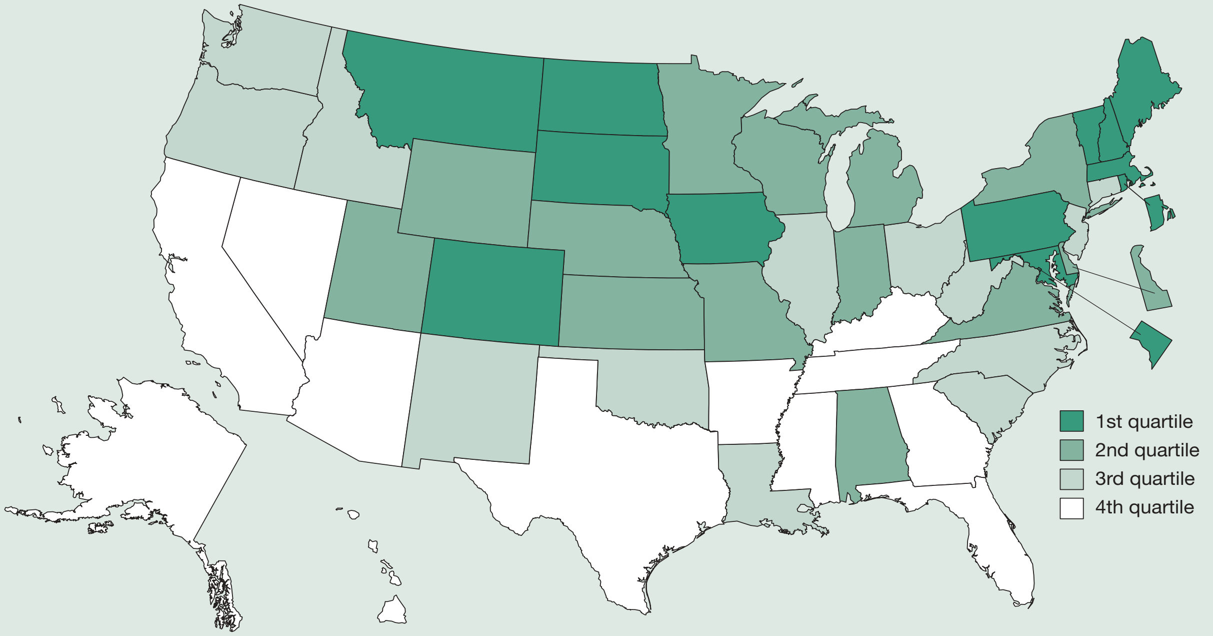
SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, various years; and U.S. Bureau of the Census, Population Division.

Science & Engineering Indicators – 2004

NS&E Bachelor's Degrees Conferred per 1,000 18–24-Year-Olds

Figure 8-5

Quartile groups for NS&E bachelor's degrees conferred per 1,000 18–24-year-olds: 2000



1st quartile (18.67–9.73)	2nd quartile (9.32–8.05)	3rd quartile (7.76–6.73)	4th quartile (6.53–3.05)
Colorado	Alabama	Connecticut	Alaska
District of Columbia	Delaware	Idaho	Arizona
Iowa	Indiana	Illinois	Arkansas
Maine	Kansas	Louisiana	California
Maryland	Michigan	New Jersey	Florida
Massachusetts	Minnesota	New Mexico	Georgia
Montana	Missouri	North Carolina	Hawaii
New Hampshire	Nebraska	Ohio	Kentucky
North Dakota	New York	Oklahoma	Mississippi
Pennsylvania	Utah	Oregon	Nevada
Rhode Island	Virginia	South Carolina	Tennessee
South Dakota	Wisconsin	Washington	Texas
Vermont	Wyoming	West Virginia	

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System; and U.S. Bureau of the Census, Population Division. See table 8-5.

Natural sciences and engineering (NS&E) include physical, earth, ocean, atmospheric, biological, agricultural and computer sciences; mathematics; and engineering. The ratio of new NS&E bachelor's degrees to the 18–24-year-old population indicates the degree to which a state prepares young people to enter the types of technology-intensive occupations that are fundamental to a knowledge-based, technology-driven economy. The 18–24-year-old cohort was chosen to approximate the age range of most people pursuing an undergraduate degree.

A high value for this indicator may suggest relative success in providing a technical undergraduate education. It may also indicate the existence of a higher education system that draws many out-of-state students into NS&E fields, which may particularly affect the results for some sparsely populated states and the District of Columbia.

Findings

- Over the past decade, the number of NS&E bachelor's degrees increased by roughly 25 percent. Nearly 170,000 degrees were awarded in 1990, and the number of degrees exceeded 200,000 in 2000. During this period, the number of 18–24-year-olds remained relatively constant.
- Reflecting the slower population cohort growth, the national average for the number of NS&E bachelor's degrees awarded per 1,000 18–24-year-olds increased from 6.3 in 1990 to 7.6 in 2000; some states, including some larger ones, had pronounced increases in this ratio.
- State values ranged from 3.1 to 14.8 and state ratings generally were in the same quartiles on this measure as on the number of bachelor's degrees conferred per 1,000 18–24-year-olds.
- In 2000, NS&E bachelor's degrees accounted for 17 percent of all bachelor's degrees awarded, up slightly from 16 percent in 1990.

Table 8-5

NS&E bachelor's degrees conferred per 1,000 18–24-year-olds, by state: 1990, 1995, and 2000

	NS&E bachelor's degrees			18–24-year-old population			NS&E bachelor's degrees per 1,000 18–24-year-olds		
State	1990	1995	2000	1990	1995	2000	1990	1995	2000
State total	167,475	190,344	207,338	26,737,766	25,112,313	27,143,454	6.26	7.58	7.64
Alabama	3,022	3,466	3,530	443,335	444,704	439,612	6.82	7.79	8.03
Alaska	200	220	240	55,847	62,426	57,292	3.58	3.52	4.19
Arizona	2,006	2,922	2,836	392,680	413,693	514,101	5.11	7.06	5.52
Arkansas	1,026	1,273	1,440	237,056	248,435	261,738	4.33	5.12	5.50
California	18,354	20,194	21,970	3,412,257	3,013,123	3,366,030	5.38	6.70	6.53
Colorado	3,548	4,492	4,709	335,525	351,400	430,111	10.57	12.78	10.95
Connecticut	1,950	2,143	1,958	345,433	270,474	271,585	5.65	7.92	7.21
Delaware	531	640	687	76,233	67,051	75,328	6.97	9.54	9.12
District of Columbia	1,032	1,187	1,356	82,558	51,875	72,637	12.50	22.88	18.67
Florida	4,793	6,077	7,333	1,215,657	1,170,757	1,330,602	3.94	5.19	5.51
Georgia	3,275	4,171	5,117	738,584	730,927	837,732	4.43	5.71	6.11
Hawaii	546	562	719	121,185	115,821	114,893	4.51	4.85	6.26
Idaho	554	793	1,013	98,247	126,435	138,829	5.64	6.27	7.30
Illinois	7,986	7,916	8,971	1,212,950	1,127,699	1,210,898	6.58	7.02	7.41
Indiana	4,623	4,887	5,113	604,882	582,508	614,721	7.64	8.39	8.32
Iowa	2,544	2,839	3,135	283,713	273,088	298,008	8.97	10.40	10.52
Kansas	1,997	2,304	2,471	254,493	251,111	275,592	7.85	9.18	8.97
Kentucky	1,685	2,044	2,266	399,989	401,248	401,858	4.21	5.09	5.64
Louisiana	2,258	2,904	3,395	464,511	460,667	473,801	4.86	6.30	7.17
Maine	726	910	1,091	123,772	112,864	103,903	5.87	8.06	10.50
Maryland	3,483	3,988	4,386	505,373	432,516	450,922	6.89	9.22	9.73
Massachusetts	6,824	6,698	7,328	709,099	538,602	579,328	9.62	12.44	12.65
Michigan	7,640	8,074	8,305	1,004,527	935,335	932,137	7.61	8.63	8.91
Minnesota	3,141	3,723	4,044	442,809	417,482	470,434	7.09	8.92	8.60
Mississippi	1,289	1,718	1,733	293,346	303,426	310,974	4.39	5.66	5.57
Missouri	3,656	4,176	4,818	517,191	499,397	535,978	7.07	8.36	8.99
Montana	860	920	1,173	70,011	83,675	85,757	12.28	10.99	13.68
Nebraska	1,026	1,312	1,581	155,887	160,166	174,425	6.58	8.19	9.06
Nevada	295	434	548	118,945	128,251	179,708	2.48	3.38	3.05
New Hampshire	1,003	1,229	1,281	117,602	96,548	103,369	8.53	12.73	12.39
New Jersey	3,772	4,267	5,249	779,184	678,491	676,628	4.84	6.29	7.76
New Mexico	990	1,134	1,229	151,824	167,305	177,576	6.52	6.78	6.92
New York	13,723	13,762	14,514	1,953,424	1,649,416	1,765,453	7.03	8.34	8.22
North Carolina	4,463	6,145	6,172	781,053	716,816	806,821	5.71	8.57	7.65
North Dakota	788	817	893	67,853	66,177	73,118	11.61	12.35	12.21
Ohio	6,978	7,480	7,828	1,136,418	1,070,668	1,056,544	6.14	6.99	7.41
Oklahoma	2,012	2,215	2,491	321,389	328,996	357,085	6.26	6.73	6.98
Oregon	1,668	1,817	2,437	267,528	282,990	327,884	6.23	6.42	7.43
Pennsylvania	10,627	11,221	11,685	1,226,775	1,074,942	1,094,449	8.66	10.44	10.68
Rhode Island	870	1,163	1,236	120,358	90,614	106,607	7.23	12.83	11.59
South Carolina	1,933	2,499	2,744	406,526	389,480	407,851	4.75	6.42	6.73
South Dakota	755	942	1,039	68,113	72,599	77,634	11.08	12.98	13.38
Tennessee	2,889	3,365	3,455	527,655	516,027	548,856	5.48	6.52	6.29
Texas	8,788	11,118	11,868	1,890,844	1,943,360	2,198,881	4.65	5.72	5.40
Utah	1,604	2,356	2,817	199,986	253,174	317,431	8.02	9.31	8.87
Vermont	677	723	840	63,166	54,240	56,586	10.72	13.33	14.84
Virginia	4,230	5,536	5,929	719,731	659,229	679,398	5.88	8.40	8.73
Washington	2,784	3,426	3,850	488,539	500,401	559,361	5.70	6.85	6.88
West Virginia	974	1,208	1,208	179,991	189,426	172,431	5.41	6.38	7.01
Wisconsin	4,776	4,520	4,850	512,326	485,889	520,629	9.32	9.30	9.32
Wyoming	301	414	457	41,386	50,369	49,928	7.27	8.22	9.15
Puerto Rico	2,074	2,468	3,033	NA	NA	428,894	NA	NA	8.41

NA not available

NS&E natural sciences and engineering

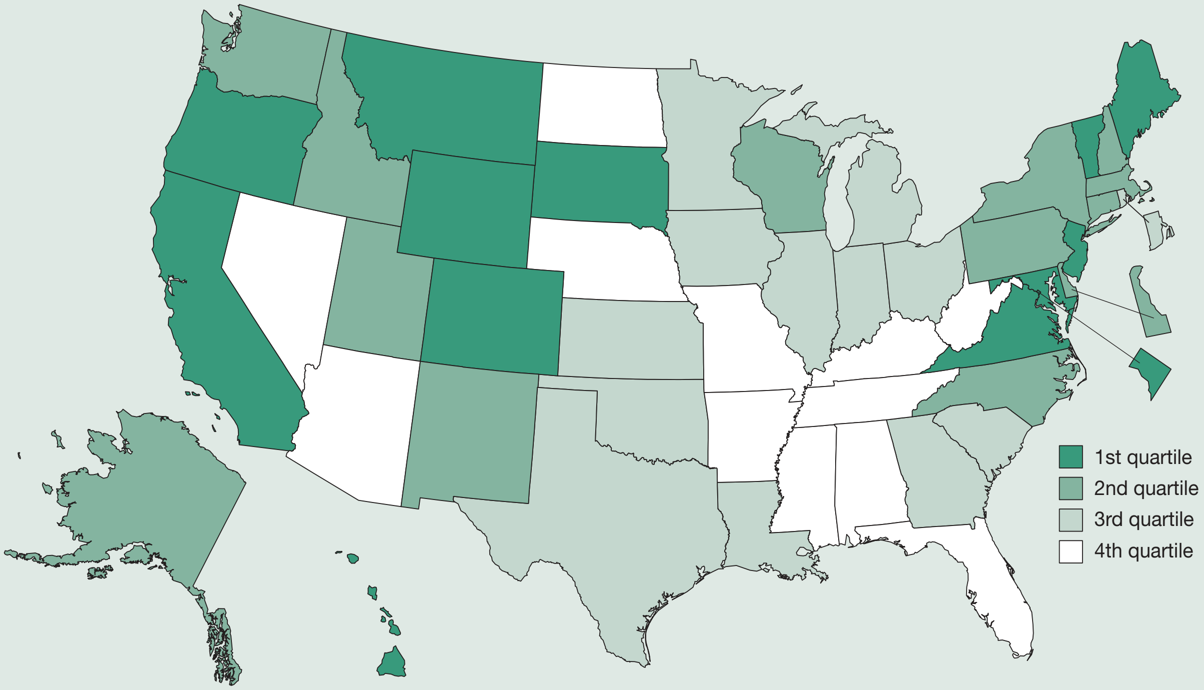
NOTES: The state total for each year is the sum of the 50 states and the District of Columbia. NS&E degrees include degrees in physical, computer, agricultural, biological, earth, atmospheric, and ocean sciences; mathematics; and engineering.

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, various years; and U.S. Bureau of the Census, Population Division.

Science & Engineering Indicators – 2004

S&E Degrees as Share of Higher Education Degrees Conferred

Figure 8-6
Quartile groups for S&E degrees as share of higher education degrees conferred: 2000



1st quartile (40.7–32.7 percent)	2nd quartile (32.6–28.8 percent)	3rd quartile (28.6–26.6 percent)	4th quartile (26.2–17.1 percent)
California	Alaska	Georgia	Alabama
Colorado	Connecticut	Illinois	Arizona
District of Columbia	Delaware	Indiana	Arkansas
Hawaii	Idaho	Iowa	Florida
Maine	Massachusetts	Kansas	Kentucky
Maryland	New Hampshire	Louisiana	Mississippi
Montana	New Mexico	Michigan	Missouri
New Jersey	New York	Minnesota	Nebraska
Oregon	North Carolina	Ohio	Nevada
South Dakota	Pennsylvania	Oklahoma	North Dakota
Vermont	Utah	Rhode Island	Tennessee
Virginia	Washington	South Carolina	West Virginia
Wyoming	Wisconsin	Texas	

SOURCE: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System. See table 8-6.

This indicator is a measure of the extent that a state's higher education programs are concentrated in science and engineering areas. The indicator is expressed as the percentage of higher education degrees that were conferred in S&E fields. High values for this indicator are from states that emphasize S&E fields in their higher education systems.

S&E includes physical, life, earth, ocean, atmospheric, computer, and social sciences; mathematics; engineering; and psychology. For both S&E degrees and higher degrees conferred, bachelor's, master's, and doctoral degrees are included; associate's degrees are excluded. The geographic location refers to the location of the degree-granting institution. The year is the latter date of the academic year. For instance, data for 2000 are degrees conferred during the 1999–2000 academic year.

Findings

- In 2000, nearly 515,000 S&E bachelor's, master's, and doctoral degrees were conferred nationwide, 20 percent more than in 1990.
- Throughout the period, S&E degrees represented about 30 percent of higher education degrees conferred nationwide.
- States ranged from 17 to nearly 41 percent on this measure in 2000.

Table 8-6
S&E degrees as share of higher education degrees conferred, by state: 1990, 1995, and 2000

	S&E degrees			All higher education degrees			S&E/higher education degrees conferred (percent)		
State	1990	1995	2000	1990	1995	2000	1990	1995	2000
All states	425,432	494,303	514,578	1,411,713	1,602,322	1,734,573	30.1	30.8	29.7
Alabama	5,468	6,692	7,486	21,923	26,345	29,740	24.9	25.4	25.2
Alaska	448	613	578	1,375	2,008	1,901	32.6	30.5	30.4
Arizona	5,022	6,818	6,691	19,887	27,051	39,047	25.3	25.2	17.1
Arkansas	1,941	2,554	2,828	9,318	10,835	11,936	20.8	23.6	23.7
California	51,407	57,575	61,388	137,935	151,478	163,630	37.3	38.0	37.5
Colorado	8,619	11,189	11,683	23,161	27,813	30,341	37.2	40.2	38.5
Connecticut	6,419	7,150	7,042	21,190	21,284	22,376	30.3	33.6	31.5
Delaware	1,470	1,856	1,931	4,367	5,670	6,238	33.7	32.7	31.0
District of Columbia	5,279	6,311	6,355	13,124	15,107	15,625	40.2	41.8	40.7
Florida	12,092	16,321	18,085	47,521	61,280	69,865	25.4	26.6	25.9
Georgia	7,858	9,862	11,288	28,629	35,887	39,763	27.4	27.5	28.4
Hawaii	1,559	1,876	2,203	4,841	6,174	6,687	32.2	30.4	32.9
Idaho	1,144	1,652	1,823	4,049	5,392	5,943	28.3	30.6	30.7
Illinois	20,570	21,309	22,749	71,412	78,983	85,255	28.8	27.0	26.7
Indiana	10,524	11,493	11,404	36,087	39,002	41,586	29.2	29.5	27.4
Iowa	5,385	6,391	6,611	19,739	21,585	23,084	27.3	29.6	28.6
Kansas	4,417	5,299	5,457	16,184	19,808	20,132	27.3	26.8	27.1
Kentucky	3,816	4,917	5,091	16,226	19,186	20,865	23.5	25.6	24.4
Louisiana	4,972	6,618	6,998	20,303	23,765	26,040	24.5	27.8	26.9
Maine	1,781	2,152	2,302	5,709	6,890	6,916	31.2	31.2	33.3
Maryland	9,609	11,001	12,201	26,795	30,735	33,531	35.9	35.8	36.4
Massachusetts	21,353	21,129	22,659	63,508	63,838	69,449	33.6	33.1	32.6
Michigan	16,889	18,447	18,420	57,038	61,325	66,966	29.6	30.1	27.5
Minnesota	7,878	9,287	8,951	27,967	30,521	31,648	28.2	30.4	28.3
Mississippi	2,589	3,599	3,397	11,471	13,355	14,602	22.6	26.9	23.3
Missouri	8,013	10,251	11,013	33,865	38,936	43,600	23.7	26.3	25.3
Montana	1,433	1,720	2,102	4,642	5,277	6,087	30.9	32.6	34.5
Nebraska	2,378	2,895	3,304	10,620	12,612	14,016	22.4	23.0	23.6
Nevada	672	1,134	1,365	2,816	4,337	5,345	23.9	26.1	25.5
New Hampshire	2,603	2,939	3,206	8,498	9,435	10,048	30.6	31.1	31.9
New Jersey	11,438	12,214	13,940	30,960	33,941	37,278	36.9	36.0	37.4
New Mexico	2,306	2,761	2,622	7,071	8,695	8,745	32.6	31.8	30.0
New York	40,748	43,600	42,967	131,126	143,457	149,317	31.1	30.4	28.8
North Carolina	10,991	14,072	14,651	34,164	40,773	46,029	32.2	34.5	31.8
North Dakota	1,374	1,440	1,519	4,893	5,152	5,798	28.1	28.0	26.2
Ohio	16,891	19,331	18,511	62,877	68,613	69,677	26.9	28.2	26.6
Oklahoma	4,412	5,306	5,982	17,952	20,649	21,353	24.6	25.7	28.0
Oregon	4,873	6,043	6,575	16,314	17,324	19,192	29.9	34.9	34.3
Pennsylvania	23,581	26,063	26,577	77,429	85,133	90,586	30.5	30.6	29.3
Rhode Island	2,744	3,185	3,012	10,774	11,430	10,696	25.5	27.9	28.2
South Carolina	4,489	5,816	6,036	17,385	19,976	21,649	25.8	29.1	27.9
South Dakota	1,407	1,930	1,871	4,573	5,482	5,722	30.8	35.2	32.7
Tennessee	6,234	7,729	8,029	23,025	27,305	31,284	27.1	28.3	25.7
Texas	21,402	27,173	27,962	80,787	95,515	103,248	26.5	28.4	27.1
Utah	4,716	5,880	6,277	13,747	17,524	20,194	34.3	33.6	31.1
Vermont	2,068	2,110	2,230	5,578	5,736	6,328	37.1	36.8	35.2
Virginia	12,033	15,434	15,662	35,117	42,026	44,808	34.3	36.7	35.0
Washington	7,806	9,278	9,627	24,123	30,145	31,740	32.4	30.8	30.3
West Virginia	1,926	2,621	2,750	9,282	11,083	11,144	20.7	23.6	24.7
Wisconsin	9,755	10,336	10,257	32,271	34,213	35,276	30.2	30.2	29.1
Wyoming	630	931	910	2,065	2,236	2,247	30.5	41.6	40.5
Puerto Rico	3,386	3,972	4,966	13,291	15,456	18,919	25.5	25.7	26.2

NOTES: The state total for each year is the sum of the 50 states and the District of Columbia. S&E degrees conferred include bachelor's, master's, and doctoral degrees. S&E degrees include degrees in physical, computer, agricultural, biological, earth, atmospheric, ocean, and social sciences; psychology; mathematics; and engineering. All degrees conferred include bachelor's, master's, and doctoral degrees.

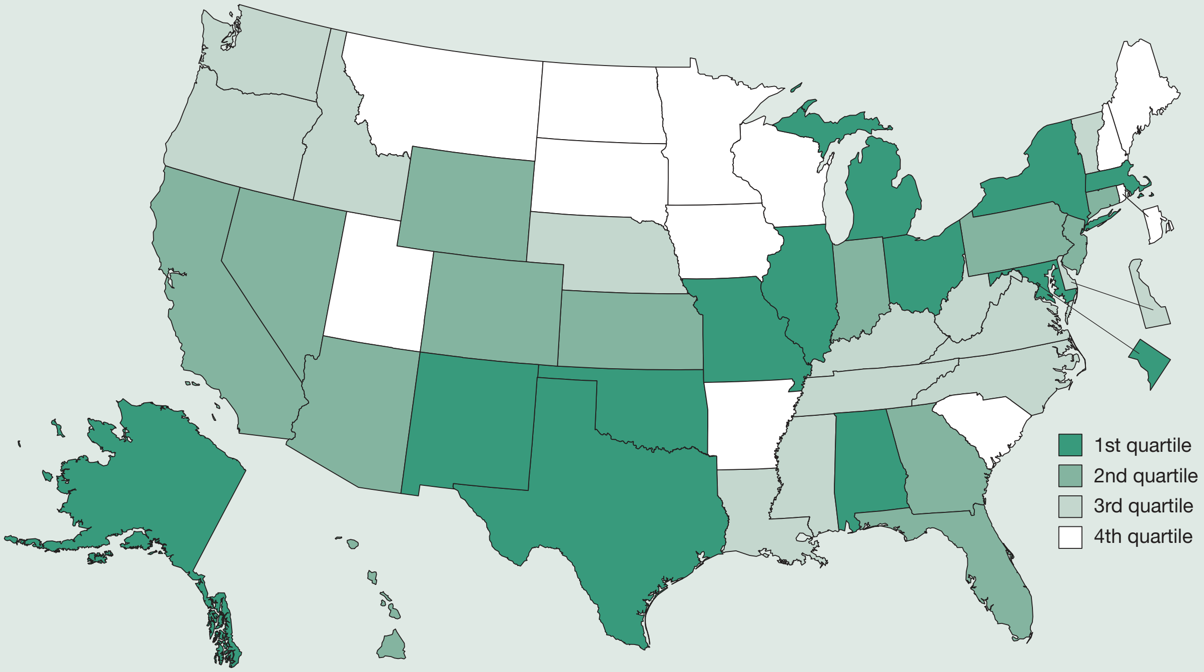
SOURCE: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, various years.

Science & Engineering Indicators – 2004

Advanced S&E Degrees as Share of S&E Degrees Conferred

Figure 8-7

Quartile groups for advanced S&E degrees as share of S&E degrees conferred, by state: 2000



1st quartile (46.8–25.0 percent)	2nd quartile (25.0–20.5 percent)	3rd quartile (20.5–17.9 percent)	4th quartile (17.5–8.0 percent)
Alabama	Arizona	Delaware	Arkansas
Alaska	California	Idaho	Iowa
District of Columbia	Colorado	Kentucky	Maine
Illinois	Connecticut	Louisiana	Minnesota
Maryland	Florida	Mississippi	Montana
Massachusetts	Georgia	Nebraska	New Hampshire
Michigan	Hawaii	North Carolina	North Dakota
Missouri	Indiana	Oregon	Rhode Island
New Mexico	Kansas	Tennessee	South Carolina
New York	Nevada	Vermont	South Dakota
Ohio	New Jersey	Virginia	Utah
Oklahoma	Pennsylvania	Washington	Wisconsin
Texas	Wyoming	West Virginia	

SOURCE: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System. See table 8-7.

This indicator shows the extent to which a state's higher education programs in science and engineering are concentrated at the graduate level. High values for this indicator are from states that emphasize graduate-level S&E training.

S&E includes physical, life, earth, ocean, atmospheric, computer, and social sciences; mathematics; engineering; and psychology. Advanced S&E degrees include master's and doctoral degrees. "All degrees" includes bachelor's, master's, and doctoral levels. Associate's degrees are excluded from this indicator.

Findings

- In 2000, about 120,000 advanced S&E degrees were awarded, approximately 20 percent more than in 1990.
- Total S&E degrees rose at a comparable rate, leaving the national percentage of advanced S&E degrees stable at about 23 percent of S&E degrees conferred nationwide.
- The indicator underwent considerable change for some states, shifting in both directions. States ranged from 8 to 33 percent on this indicator in 2000.
- The District of Columbia was an outlier at 47 percent.
- States that emphasize advanced S&E training are not necessarily the same as those that emphasize bachelor's-level S&E education; only half the states in the top two quartiles on one indicator appear in the top two on the other.

Table 8-7

Advanced S&E degrees as share of S&E degrees conferred, by state: 1990, 1995, and 2000

	Advanced S&E degrees			All S&E degrees			Advanced/all S&E degrees conferred (percent)		
State	1990	1995	2000	1990	1995	2000	1990	1995	2000
All states	99,457	119,778	120,277	425,432	494,303	514,578	23.4	24.2	23.4
Alabama	1,143	1,463	1,937	5,468	6,692	7,486	20.9	21.9	25.9
Alaska	130	215	185	448	613	578	29.0	35.1	32.0
Arizona	1,310	1,816	1,674	5,022	6,818	6,691	26.1	26.6	25.0
Arkansas	325	408	436	1,941	2,554	2,828	16.7	16.0	15.4
California	13,267	14,815	15,059	51,407	57,575	61,388	25.8	25.7	24.5
Colorado	1,993	2,911	2,894	8,619	11,189	11,683	23.1	26.0	24.8
Connecticut	1,658	1,765	1,748	6,419	7,150	7,042	25.8	24.7	24.8
Delaware	270	349	394	1,470	1,856	1,931	18.4	18.8	20.4
District of Columbia	2,059	2,910	2,972	5,279	6,311	6,355	39.0	46.1	46.8
Florida	2,764	3,940	4,012	12,092	16,321	18,085	22.9	24.1	22.2
Georgia	1,718	2,270	2,371	7,858	9,862	11,288	21.9	23.0	21.0
Hawaii	330	454	543	1,559	1,876	2,203	21.2	24.2	24.6
Idaho	303	418	331	1,144	1,652	1,823	26.5	25.3	18.2
Illinois	5,368	6,161	6,777	20,570	21,309	22,749	26.1	28.9	29.8
Indiana	2,178	2,551	2,483	10,524	11,493	11,404	20.7	22.2	21.8
Iowa	1,064	1,200	1,055	5,385	6,391	6,611	19.8	18.8	16.0
Kansas	1,000	1,191	1,220	4,417	5,299	5,457	22.6	22.5	22.4
Kentucky	810	940	938	3,816	4,917	5,091	21.2	19.1	18.4
Louisiana	1,047	1,526	1,430	4,972	6,618	6,998	21.1	23.1	20.4
Maine	175	226	185	1,781	2,152	2,302	9.8	10.5	8.0
Maryland	2,570	3,196	3,639	9,609	11,001	12,201	26.7	29.1	29.8
Massachusetts	5,787	6,139	6,597	21,353	21,129	22,659	27.1	29.1	29.1
Michigan	3,616	4,567	4,788	16,889	18,447	18,420	21.4	24.8	26.0
Minnesota	1,282	1,576	1,540	7,878	9,287	8,951	16.3	17.0	17.2
Mississippi	605	782	628	2,589	3,599	3,397	23.4	21.7	18.5
Missouri	2,086	2,700	2,793	8,013	10,251	11,013	26.0	26.3	25.4
Montana	251	346	368	1,433	1,720	2,102	17.5	20.1	17.5
Nebraska	512	586	647	2,378	2,895	3,304	21.5	20.2	19.6
Nevada	180	288	315	672	1,134	1,365	26.8	25.4	23.1
New Hampshire	343	424	418	2,603	2,939	3,206	13.2	14.4	13.0
New Jersey	3,038	3,040	3,118	11,438	12,214	13,940	26.6	24.9	22.4
New Mexico	694	898	697	2,306	2,761	2,622	30.1	32.5	26.6
New York	10,796	11,606	10,752	40,748	43,600	42,967	26.5	26.6	25.0
North Carolina	1,782	2,351	2,630	10,991	14,072	14,651	16.2	16.7	18.0
North Dakota	238	222	190	1,374	1,440	1,519	17.3	15.4	12.5
Ohio	4,456	5,155	4,635	16,891	19,331	18,511	26.4	26.7	25.0
Oklahoma	1,139	1,542	1,981	4,412	5,306	5,982	25.8	29.1	33.1
Oregon	1,034	1,348	1,227	4,873	6,043	6,575	21.2	22.3	18.7
Pennsylvania	4,499	5,660	5,448	23,581	26,063	26,577	19.1	21.7	20.5
Rhode Island	599	663	509	2,744	3,185	3,012	21.8	20.8	16.9
South Carolina	723	1,072	980	4,489	5,816	6,036	16.1	18.4	16.2
South Dakota	234	370	307	1,407	1,930	1,871	16.6	19.2	16.4
Tennessee	1,192	1,427	1,497	6,234	7,729	8,029	19.1	18.5	18.6
Texas	5,236	7,138	7,131	21,402	27,173	27,962	24.5	26.3	25.5
Utah	962	1,048	1,032	4,716	5,880	6,277	20.4	17.8	16.4
Vermont	312	306	409	2,068	2,110	2,230	15.1	14.5	18.3
Virginia	2,396	3,275	3,208	12,033	15,434	15,662	19.9	21.2	20.5
Washington	1,797	1,923	1,722	7,806	9,278	9,627	23.0	20.7	17.9
West Virginia	317	437	546	1,926	2,621	2,750	16.5	16.7	19.9
Wisconsin	1,679	1,874	1,656	9,755	10,336	10,257	17.2	18.1	16.1
Wyoming	190	290	225	630	931	910	30.2	31.1	24.7
Puerto Rico	325	434	759	3,386	3,972	4,966	9.6	10.9	15.3

NOTES: The state total for each year is the sum of the 50 states and the District of Columbia. “All degrees” includes bachelor’s, master’s, and doctoral degrees; advanced degrees include only master’s and doctoral degrees. S&E degrees include degrees in physical, computer, agricultural, biological, earth, atmospheric, ocean, and social sciences; psychology; mathematics; and engineering.

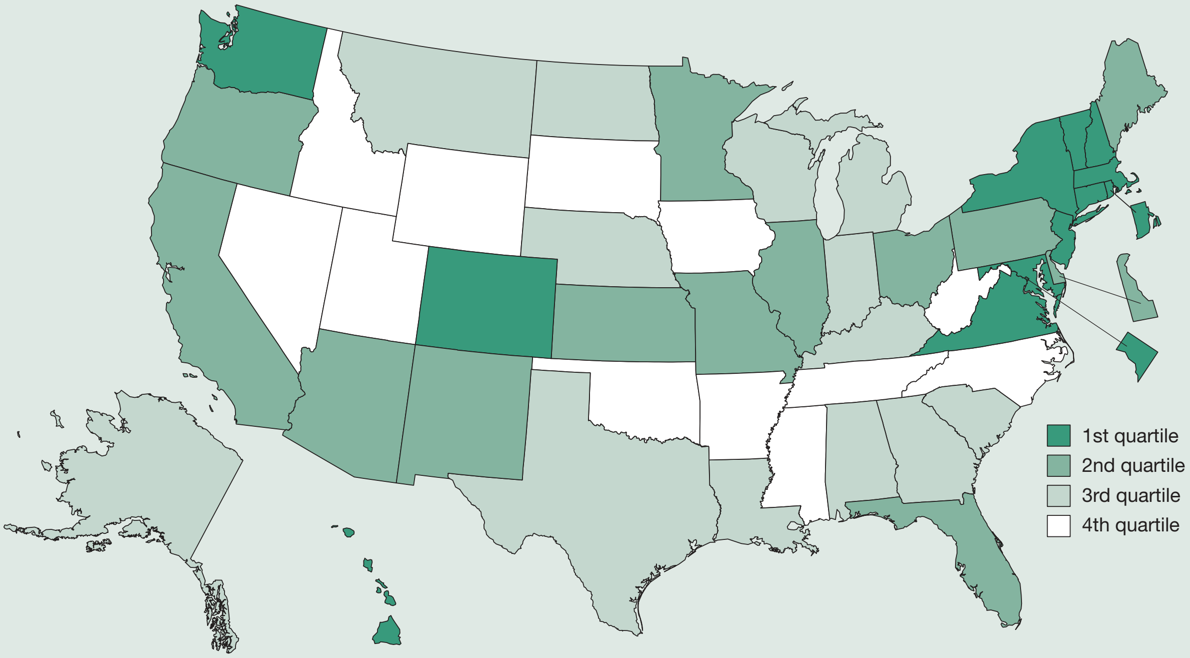
SOURCE: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, various years.

Science & Engineering Indicators – 2004

Bachelor's Degree Holders as Share of Workforce

Figure 8-8

Quartile groups for bachelor's degree holders as share of workforce: 2002



1st quartile (59.7–37.9 percent)	2nd quartile (37.9–33.2 percent)	3rd quartile (33.0–30.4 percent)	4th quartile (30.3–24.3 percent)
Colorado	Arizona	Alabama	Arkansas
Connecticut	California	Alaska	Idaho
District of Columbia	Delaware	Georgia	Iowa
Hawaii	Florida	Indiana	Mississippi
Maryland	Illinois	Kentucky	Nevada
Massachusetts	Kansas	Louisiana	North Carolina
New Hampshire	Maine	Michigan	Oklahoma
New Jersey	Minnesota	Montana	South Dakota
New York	Missouri	Nebraska	Tennessee
Rhode Island	New Mexico	North Dakota	Utah
Vermont	Ohio	South Carolina	West Virginia
Virginia	Oregon	Texas	Wyoming
Washington	Pennsylvania	Wisconsin	

SOURCES: U.S. Bureau of the Census, Population Division, Education and Stratification Branch, *Educational Attainment in the United States;* and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics. See table 8-8.

Bachelor's degrees are considered an indicator of a well-educated workforce because of the clear advantage they provide over less educational attainment in terms of expected lifetime earnings. The indicator is expressed as the percentage of workers in a state's workforce who hold at least a bachelor's degree. A high value for this indicator denotes that the state has a large percentage of workers who completed an undergraduate education.

Degree data, based on the Census Bureau's Current Population Survey (CPS), are limited to individuals who are age 25 or older. Civilian workforce data are Bureau of Labor Statistics estimates based on CPS. Estimates for sparsely populated states and the District of Columbia may be imprecise because of their small representation in the survey samples.

Findings

- In 2002, there were 48.7 million bachelor's degree holders in the United States, up from 35.6 million in 1993.
- The nationwide value of this indicator rose from 29.6 percent in 1993 to 35.6 percent in 2002, indicating a significant increase in the number and percentage of workers who completed a baccalaureate.
- The proportion of the workforce with a bachelor's degree increased considerably in many states, possibly reflecting the states' attraction of younger cohorts of workers with relatively more college-educated people than older cohorts or a restructuring of their economies.
- The geographic distribution of bachelor's degree holders in the workforce bears little resemblance to any of the degree-based indicators, attesting to the considerable mobility of the U.S. college-educated population.

Table 8-8
Bachelor's degree holders as share of workforce, by state: 1993, 1997, and 2002

	Bachelor's degree holders (thousands)			Workforce			Bachelor's degree holders in workforce (percent)		
State	1993	1997	2002	1993	1997	2002	1993	1997	2002
All states	35,605	40,695	48,697	120,303,214	129,540,407	136,945,620	29.6	31.4	35.6
Alabama	380	535	652	1,845,425	2,057,160	1,978,462	20.6	26.0	33.0
Alaska	73	106	98	274,788	289,735	297,831	26.6	36.6	32.9
Arizona	544	561	837	1,715,112	2,080,658	2,506,677	31.7	27.0	33.4
Arkansas	234	233	310	1,092,878	1,147,974	1,215,663	21.4	20.3	25.5
California	4,922	5,563	5,847	13,918,275	14,942,526	16,241,776	35.4	37.2	36.0
Colorado	645	688	993	1,800,035	2,080,012	2,297,565	35.8	33.1	43.2
Connecticut	612	655	754	1,672,617	1,634,771	1,696,155	36.6	40.1	44.5
Delaware	105	127	153	354,352	365,650	405,339	29.6	34.7	37.7
District of Columbia	133	125	170	280,873	237,189	284,553	47.4	52.7	59.7
Florida	1,847	2,137	2,840	6,191,793	6,780,081	7,642,161	29.8	31.5	37.2
Georgia	883	1,045	1,284	3,265,259	3,727,295	4,071,469	27.0	28.0	31.5
Hawaii	194	172	214	560,898	556,673	557,456	34.6	30.9	38.4
Idaho	122	142	169	513,653	600,465	644,572	23.8	23.6	26.2
Illinois	1,677	1,857	2,208	5,570,146	5,912,684	5,963,317	30.1	31.4	37.0
Indiana	506	608	962	2,785,578	2,978,607	3,011,785	18.2	20.4	31.9
Iowa	330	397	431	1,497,084	1,527,935	1,600,709	22.0	26.0	26.9
Kansas	383	434	508	1,256,952	1,326,289	1,342,010	30.5	32.7	37.9
Kentucky	410	438	566	1,689,935	1,812,779	1,856,567	24.3	24.2	30.5
Louisiana	420	478	599	1,746,168	1,889,133	1,882,731	24.1	25.3	31.8
Maine	168	167	218	582,047	625,790	656,064	28.9	26.7	33.2
Maryland	849	1,055	1,298	2,505,102	2,640,878	2,771,882	33.9	39.9	46.8
Massachusetts	1,188	1,360	1,494	2,945,402	3,130,763	3,301,276	40.3	43.4	45.3
Michigan	1,128	1,273	1,485	4,418,025	4,752,196	4,691,095	25.5	26.8	31.7
Minnesota	655	835	997	2,349,196	2,537,651	2,789,929	27.9	32.9	35.7
Mississippi	274	346	367	1,138,166	1,189,825	1,209,733	24.1	29.1	30.3
Missouri	647	780	948	2,489,049	2,768,598	2,825,055	26.0	28.2	33.6
Montana	112	142	140	400,259	430,261	442,472	28.0	33.0	31.6
Nebraska	186	222	288	835,581	881,901	924,870	22.3	25.2	31.1
Nevada	150	215	300	689,404	846,319	1,059,890	21.8	25.4	28.3
New Hampshire	199	209	263	575,418	625,386	672,363	34.6	33.4	39.1
New Jersey	1,440	1,506	1,851	3,690,762	3,976,900	4,112,788	39.0	37.9	45.0
New Mexico	214	249	283	697,828	763,254	829,775	30.7	32.6	34.1
New York	2,807	3,051	3,571	7,973,256	8,276,305	8,789,721	35.2	36.9	40.6
North Carolina	811	1,075	1,150	3,380,985	3,702,936	3,890,025	24.0	29.0	29.6
North Dakota	80	80	107	306,234	338,691	332,199	26.1	23.6	32.2
Ohio	1,385	1,553	1,840	5,130,907	5,452,225	5,497,213	27.0	28.5	33.5
Oklahoma	409	433	441	1,435,793	1,529,590	1,616,774	28.5	28.3	27.3
Oregon	459	507	601	1,479,939	1,626,986	1,695,275	31.0	31.2	35.5
Pennsylvania	1,516	1,837	2,142	5,470,346	5,666,669	5,933,923	27.7	32.4	36.1
Rhode Island	134	171	211	471,628	475,819	528,231	28.4	35.9	39.9
South Carolina	371	447	603	1,686,920	1,844,062	1,851,214	22.0	24.2	32.6
South Dakota	87	90	116	348,461	374,362	407,883	25.0	24.0	28.4
Tennessee	477	609	797	2,356,704	2,564,781	2,776,401	20.2	23.7	28.7
Texas	2,382	2,624	3,307	8,503,521	9,309,966	10,069,800	28.0	28.2	32.8
Utah	207	290	326	879,788	1,006,997	1,107,946	23.5	28.8	29.4
Vermont	92	89	130	298,748	314,053	335,623	30.8	28.3	38.7
Virginia	1,039	1,236	1,612	3,207,393	3,273,222	3,583,240	32.4	37.8	45.0
Washington	907	933	1,089	2,495,453	2,839,863	2,871,015	36.3	32.9	37.9
West Virginia	142	182	195	702,895	747,677	755,288	20.2	24.3	25.8
Wisconsin	618	760	869	2,598,025	2,840,345	2,860,916	23.8	26.8	30.4
Wyoming	52	68	63	228,158	238,520	258,943	22.8	28.5	24.3
Puerto Rico	NA	NA	NA	1,003,885	1,131,925	1,189,957	NA	NA	NA

NA not available

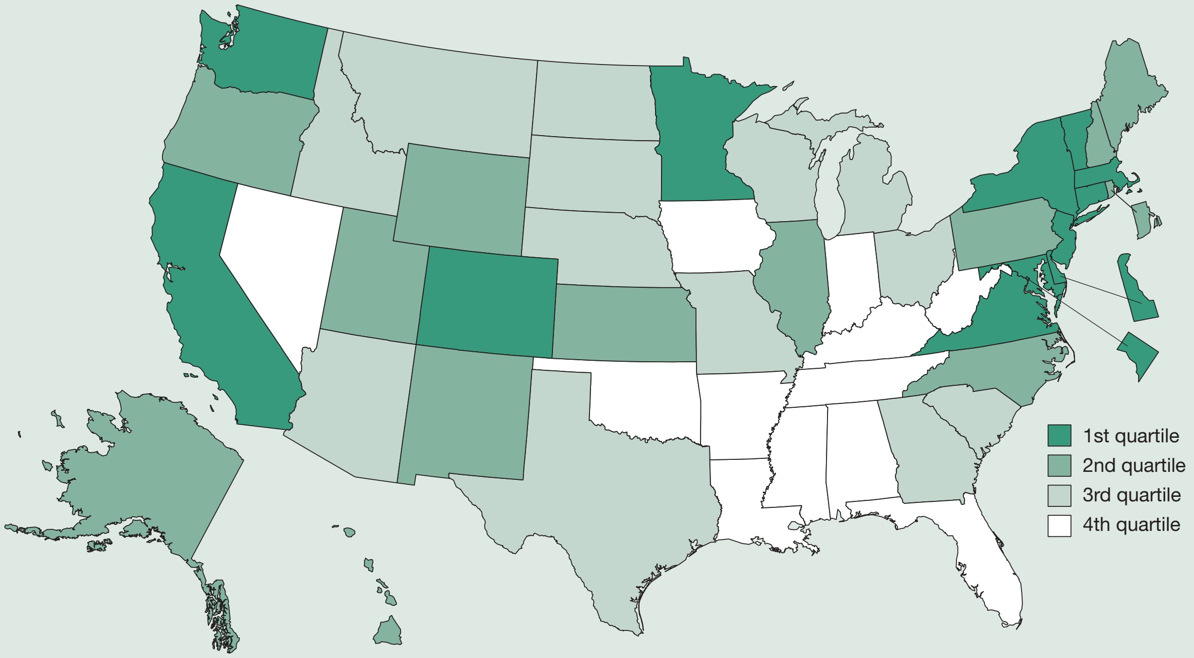
NOTES: The state total for each year is the sum of the 50 states and the District of Columbia. Bachelor's degree holders include those who have completed a bachelor's degree or higher. Workforce represents the employed component of the civilian labor force and is reported as annual data, not seasonally adjusted.

SOURCES: U.S. Bureau of the Census, Population Division, Education and Social Stratification Branch, *Educational Attainment in the United States,* various years; and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics.

Science & Engineering Indicators – 2004

Scientists and Engineers as Share of Workforce

Figure 8-9
Quartile groups for scientists and engineers as share of workforce: 1999



1st quartile (67.30–9.53 percent)	2nd quartile (9.46–7.44 percent)	3rd quartile (7.43–6.25 percent)	4th quartile (6.17–4.19 percent)
California	Alaska	Arizona	Alabama
Colorado	Hawaii	Georgia	Arkansas
Connecticut	Illinois	Idaho	Florida
Delaware	Kansas	Michigan	Indiana
District of Columbia	Maine	Missouri	Iowa
Maryland	New Hampshire	Montana	Kentucky
Massachusetts	New Mexico	Nebraska	Louisiana
Minnesota	North Carolina	North Dakota	Mississippi
New Jersey	Oregon	Ohio	Nevada
New York	Pennsylvania	South Carolina	Oklahoma
Vermont	Rhode Island	South Dakota	Tennessee
Virginia	Utah	Texas	West Virginia
Washington	Wyoming	Wisconsin	

SOURCES: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT); and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics. See table 8-9.

This indicator shows the extent to which a state's workforce provides a labor pool with the training to work in technical areas or in jobs with technical content. Scientists and engineers are people with a bachelor's or higher degree in a science or engineering field or who worked in an S&E occupation in 1993.

Civilian workforce data are Bureau of Labor Statistics (BLS) estimates based on the Current Population Survey. BLS data are based on residence location, whereas data for scientists and engineers are largely classified based on work location. Because of this difference and the sample-based nature of the data, estimates for sparsely populated states and the District of Columbia may be imprecise.

Findings

- In 1999, 10.9 million scientists and engineers were employed in the United States, up from 10.1 million in 1995.
- The nation's overall workforce grew at essentially the same rate, keeping the proportion of scientists and engineers at around 8 percent of the civilian workforce for the period.
- Large workforce shares of scientists and engineers are evident on both U.S. coasts and in the southern Rocky Mountain area.

Table 8-9
Scientists and engineers as share of workforce, by state: 1995, 1997, and 1999

	Employed scientists and engineers			Workforce			Scientists and engineers in workforce (percent)		
State	1995	1997	1999	1995	1997	1999	1995	1997	1999
All states	10,093,900	10,551,600	10,935,300	125,091,085	129,540,407	133,397,374	8.07	8.15	8.20
Alabama	111,900	114,800	120,600	1,938,772	2,057,160	2,038,912	5.77	5.58	5.91
Alaska	26,500	27,200	24,000	280,829	289,735	298,577	9.44	9.39	8.04
Arizona	139,100	145,500	145,100	2,079,452	2,080,658	2,255,117	6.69	6.99	6.43
Arkansas	42,600	50,000	55,000	1,160,396	1,147,974	1,173,971	3.67	4.36	4.68
California	1,430,500	1,461,200	1,499,300	14,202,849	14,942,526	15,731,727	10.07	9.78	9.53
Colorado	230,100	246,000	264,000	2,000,022	2,080,012	2,198,147	11.50	11.83	12.01
Connecticut	191,400	192,000	196,100	1,616,855	1,634,771	1,654,455	11.84	11.74	11.85
Delaware	41,000	44,000	44,500	365,413	365,650	375,970	11.22	12.03	11.84
District of Columbia	180,200	169,000	177,100	258,833	237,189	263,158	69.62	71.25	67.30
Florida	378,100	391,200	403,800	6,474,776	6,780,081	7,076,924	5.84	5.77	5.71
Georgia	247,800	258,900	266,900	3,440,859	3,727,295	3,916,080	7.20	6.95	6.82
Hawaii	55,000	48,000	46,200	542,632	556,673	559,587	10.14	8.62	8.26
Idaho	39,300	43,500	42,100	568,138	600,465	617,393	6.92	7.24	6.82
Illinois	457,700	481,900	480,700	5,796,094	5,912,684	6,105,124	7.90	8.15	7.87
Indiana	161,200	171,700	184,000	2,980,499	2,978,607	2,982,597	5.41	5.76	6.17
Iowa	78,300	88,200	88,200	1,505,094	1,527,935	1,532,729	5.20	5.77	5.75
Kansas	109,400	112,000	117,200	1,278,543	1,326,289	1,391,523	8.56	8.44	8.42
Kentucky	89,500	90,700	86,600	1,760,990	1,812,779	1,878,686	5.08	5.00	4.61
Louisiana	99,900	93,700	94,500	1,818,362	1,889,133	1,947,655	5.49	4.96	4.85
Maine	45,600	49,900	52,900	603,231	625,790	642,471	7.56	7.97	8.23
Maryland	269,400	285,000	298,800	2,576,688	2,640,878	2,676,488	10.46	10.79	11.16
Massachusetts	413,900	430,300	445,900	2,994,372	3,130,763	3,179,102	13.82	13.74	14.03
Michigan	300,300	323,900	344,000	4,556,351	4,752,196	4,950,204	6.59	6.82	6.95
Minnesota	226,900	245,400	264,000	2,498,821	2,537,651	2,627,437	9.08	9.67	10.05
Mississippi	53,600	53,500	55,900	1,180,018	1,189,825	1,202,968	4.54	4.50	4.65
Missouri	160,000	169,300	181,100	2,697,866	2,768,598	2,745,464	5.93	6.12	6.60
Montana	29,200	33,000	33,400	411,306	430,261	449,361	7.10	7.67	7.43
Nebraska	56,400	62,400	63,900	874,357	881,901	885,755	6.45	7.08	7.21
Nevada	38,300	38,300	37,700	758,992	846,319	899,737	5.05	4.53	4.19
New Hampshire	50,000	56,900	61,500	608,088	625,386	649,969	8.22	9.10	9.46
New Jersey	374,500	379,000	386,400	3,803,748	3,976,900	4,012,218	9.85	9.53	9.63
New Mexico	67,500	67,100	70,800	741,426	763,254	763,609	9.10	8.79	9.27
New York	800,800	824,700	849,600	7,970,087	8,276,305	8,422,650	10.05	9.96	10.09
North Carolina	257,100	282,500	325,600	3,473,478	3,702,936	3,746,412	7.40	7.63	8.69
North Dakota	19,300	19,700	21,000	324,613	338,691	325,366	5.95	5.82	6.45
Ohio	352,500	387,400	384,400	5,318,880	5,452,225	5,507,825	6.63	7.11	6.98
Oklahoma	86,900	96,200	97,200	1,473,610	1,529,590	1,597,865	5.90	6.29	6.08
Oregon	124,700	135,400	142,700	1,572,628	1,626,986	1,660,724	7.93	8.32	8.59
Pennsylvania	427,800	443,200	457,200	5,494,532	5,666,669	5,713,423	7.79	7.82	8.00
Rhode Island	46,400	42,400	42,600	453,512	475,819	483,532	10.23	8.91	8.81
South Carolina	101,600	113,700	117,200	1,770,523	1,844,062	1,875,433	5.74	6.17	6.25
South Dakota	25,800	26,600	28,800	375,303	374,362	388,072	6.87	7.11	7.42
Tennessee	144,600	148,600	151,300	2,560,613	2,564,781	2,702,168	5.65	5.79	5.60
Texas	639,700	648,900	678,400	9,011,013	9,309,966	9,746,879	7.10	6.97	6.96
Utah	74,800	75,800	77,800	951,372	1,006,997	1,045,501	7.86	7.53	7.44
Vermont	33,000	31,600	33,200	305,277	314,053	325,585	10.81	10.06	10.20
Virginia	304,500	333,400	347,000	3,325,234	3,273,222	3,429,908	9.16	10.19	10.12
Washington	235,900	290,000	313,500	2,630,924	2,839,863	2,929,243	8.97	10.21	10.70
West Virginia	32,000	35,200	37,000	723,140	747,677	762,573	4.43	4.71	4.85
Wisconsin	168,600	172,300	176,400	2,738,522	2,840,345	2,801,777	6.16	6.07	6.30
Wyoming	22,800	20,500	22,200	243,152	238,520	249,323	9.38	8.59	8.90
Puerto Rico	NA	NA	NA	1,074,411	1,131,925	1,148,959	NA	NA	NA

NA not available

NOTES: The state total for each year is the sum of the 50 states and the District of Columbia. Scientists and engineers include people who were employed at time of survey who are included in one of the following groups: (1) have ever received a bachelor's degree or higher in an S&E field or (2) have a non-S&E bachelor's or higher degree and were in an S&E occupation at the time of the 1993 Scientists and Engineers Statistical Data System (SESTAT) surveys. Because SESTAT survey sample designs do not include geography, reliability of estimates in some states may be poor because of small sample size. Workforce represents the employed component of the civilian labor force and is reported as annual data, not seasonally adjusted.

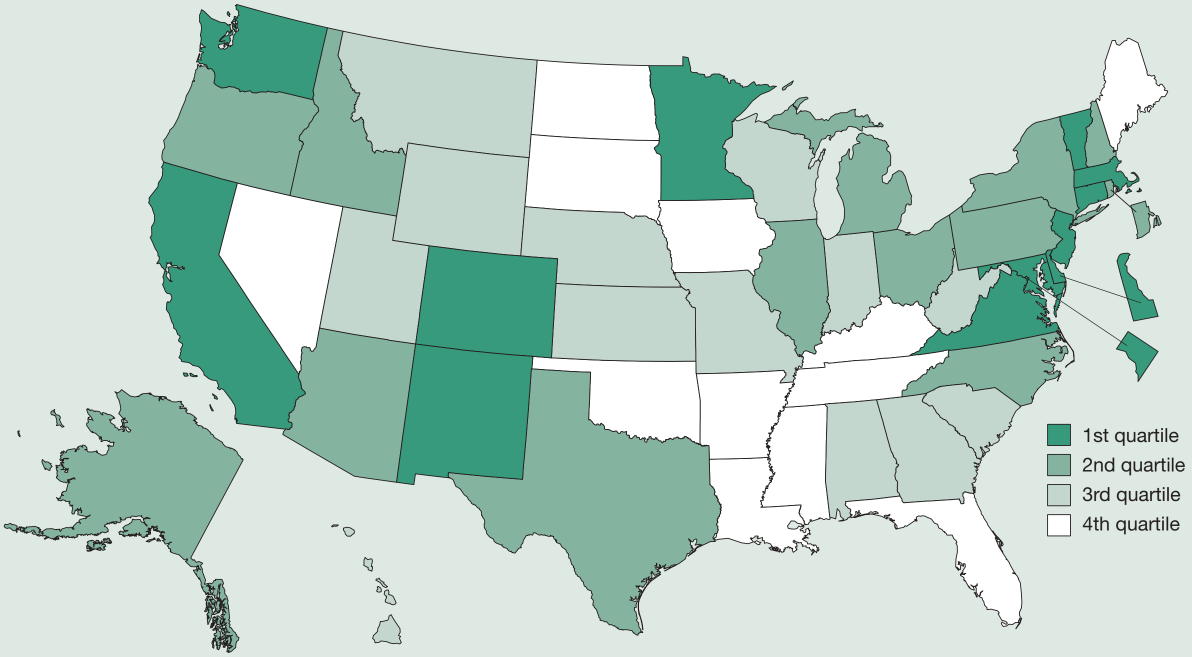
SOURCES: National Science Foundation, Division of Science Resources Statistics, SESTAT; and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics.

Science & Engineering Indicators – 2004

S&E Occupations as Share of Workforce

Figure 8-10

Quartile groups for individuals in S&E occupations as share of workforce: 1999



1st quartile (20.48–3.02 percent)	2nd quartile (2.94–2.41 percent)	3rd quartile (2.41–1.88 percent)	4th quartile (1.82–1.20 percent)
California	Alaska	Alabama	Arkansas
Colorado	Arizona	Georgia	Florida
Connecticut	Idaho	Hawaii	Iowa
Delaware	Illinois	Indiana	Kentucky
District of Columbia	Michigan	Kansas	Louisiana
Maryland	New Hampshire	Missouri	Maine
Massachusetts	New York	Montana	Mississippi
Minnesota	North Carolina	Nebraska	Nevada
New Jersey	Ohio	South Carolina	North Dakota
New Mexico	Oregon	Utah	Oklahoma
Vermont	Pennsylvania	West Virginia	South Dakota
Virginia	Rhode Island	Wisconsin	Tennessee
Washington	Texas	Wyoming	

SOURCES: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT); and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics. See table 8-10.

This indicator shows the extent to which a state's workforce is college educated and employed in science and engineering occupations. A high value for this indicator shows that a state's economy has a high percentage of technical jobs relative to other states.

S&E occupations include mathematical, computer, life, physical, and social scientists; engineers; and postsecondary teachers in any of these S&E fields. People with job titles such as manager are excluded.

Civilian workforce data are Bureau of Labor Statistics (BLS) estimates based on the Current Population Survey. BLS data are based on residence location, whereas data on people in S&E occupations are largely based on work location. Because of this difference and the sample-based nature of the data, estimates for sparsely populated states and the District of Columbia may be imprecise.

Findings

- In 1999, about 3.5 million people worked in occupations classified as S&E.
- The concentration of S&E occupations in the workforce varied little since 1995, averaging 2.5–2.6 percent across the United States.
- States located in the Northeast, Southwest, and West Coast tend to be in the top two quartiles on this measure. The District of Columbia is an outlier.

Table 8-10
Individuals in S&E occupations as share of workforce, by state: 1995, 1997, and 1999

	S&E occupations			Workforce			Workforce in S&E occupations (percent)		
State	1995	1997	1999	1995	1997	1999	1995	1997	1999
All states	3,178,000	3,357,000	3,525,100	125,091,085	129,540,407	133,397,374	2.54	2.59	2.64
Alabama	40,800	44,300	43,300	1,938,772	2,057,160	2,038,912	2.10	2.15	2.12
Alaska	6,600	6,300	7,700	280,829	289,735	298,577	2.35	2.17	2.58
Arizona	47,400	54,000	55,700	2,079,452	2,080,658	2,255,117	2.28	2.60	2.47
Arkansas	14,100	15,300	16,900	1,160,396	1,147,974	1,173,971	1.22	1.33	1.44
California	463,900	478,000	492,000	14,202,849	14,942,526	15,731,727	3.27	3.20	3.13
Colorado	82,700	88,500	96,900	2,000,022	2,080,012	2,198,147	4.13	4.25	4.41
Connecticut	56,900	53,300	57,500	1,616,855	1,634,771	1,654,455	3.52	3.26	3.48
Delaware	14,300	15,700	16,300	365,413	365,650	375,970	3.91	4.29	4.34
District of Columbia	53,200	51,300	53,900	258,833	237,189	263,158	20.55	21.63	20.48
Florida	105,500	116,600	123,000	6,474,776	6,780,081	7,076,924	1.63	1.72	1.74
Georgia	69,800	75,600	85,900	3,440,859	3,727,295	3,916,080	2.03	2.03	2.19
Hawaii	13,100	11,500	11,700	542,632	556,673	559,587	2.41	2.07	2.09
Idaho	13,200	13,900	15,500	568,138	600,465	617,393	2.32	2.31	2.51
Illinois	138,300	148,600	155,200	5,796,094	5,912,684	6,105,124	2.39	2.51	2.54
Indiana	51,300	54,000	56,000	2,980,499	2,978,607	2,982,597	1.72	1.81	1.88
Iowa	22,100	24,500	23,900	1,505,094	1,527,935	1,532,729	1.47	1.60	1.56
Kansas	29,500	34,300	31,400	1,278,543	1,326,289	1,391,523	2.31	2.59	2.26
Kentucky	22,700	23,100	26,100	1,760,990	1,812,779	1,878,686	1.29	1.27	1.39
Louisiana	35,900	36,200	35,500	1,818,362	1,889,133	1,947,655	1.97	1.92	1.82
Maine	7,900	11,600	11,200	603,231	625,790	642,471	1.31	1.85	1.74
Maryland	93,300	93,900	104,100	2,576,688	2,640,878	2,676,488	3.62	3.56	3.89
Massachusetts	130,900	136,600	148,800	2,994,372	3,130,763	3,179,102	4.37	4.36	4.68
Michigan	116,700	122,900	131,800	4,556,351	4,752,196	4,950,204	2.56	2.59	2.66
Minnesota	69,400	76,800	81,600	2,498,821	2,537,651	2,627,437	2.78	3.03	3.11
Mississippi	15,700	14,100	16,100	1,180,018	1,189,825	1,202,968	1.33	1.19	1.34
Missouri	53,100	59,700	61,000	2,697,866	2,768,598	2,745,464	1.97	2.16	2.22
Montana	8,100	10,200	8,600	411,306	430,261	449,361	1.97	2.37	1.91
Nebraska	15,300	15,200	19,900	874,357	881,901	885,755	1.75	1.72	2.25
Nevada	11,600	10,100	10,800	758,992	846,319	899,737	1.53	1.19	1.20
New Hampshire	14,000	17,000	19,100	608,088	625,386	649,969	2.30	2.72	2.94
New Jersey	118,900	118,500	121,200	3,803,748	3,976,900	4,012,218	3.13	2.98	3.02
New Mexico	25,100	25,900	28,600	741,426	763,254	763,609	3.39	3.39	3.75
New York	197,400	206,900	216,000	7,970,087	8,276,305	8,422,650	2.48	2.50	2.56
North Carolina	75,000	84,500	93,800	3,473,478	3,702,936	3,746,412	2.16	2.28	2.50
North Dakota	4,500	4,300	4,700	324,613	338,691	325,366	1.39	1.27	1.44
Ohio	119,900	138,600	132,900	5,318,880	5,452,225	5,507,825	2.25	2.54	2.41
Oklahoma	25,500	28,600	28,100	1,473,610	1,529,590	1,597,865	1.73	1.87	1.76
Oregon	37,800	39,800	43,400	1,572,628	1,626,986	1,660,724	2.40	2.45	2.61
Pennsylvania	137,700	141,800	143,300	5,494,532	5,666,669	5,713,423	2.51	2.50	2.51
Rhode Island	15,600	13,500	14,200	453,512	475,819	483,532	3.44	2.84	2.94
South Carolina	31,800	34,200	37,500	1,770,523	1,844,062	1,875,433	1.80	1.85	2.00
South Dakota	5,400	5,400	7,000	375,303	374,362	388,072	1.44	1.44	1.80
Tennessee	50,400	47,100	44,400	2,560,613	2,564,781	2,702,168	1.97	1.84	1.64
Texas	229,600	232,300	254,800	9,011,013	9,309,966	9,746,879	2.55	2.50	2.61
Utah	26,100	24,400	25,200	951,372	1,006,997	1,045,501	2.74	2.42	2.41
Vermont	8,800	10,200	12,500	305,277	314,053	325,585	2.88	3.25	3.84
Virginia	104,500	116,200	124,100	3,325,234	3,273,222	3,429,908	3.14	3.55	3.62
Washington	75,800	97,900	101,500	2,630,924	2,839,863	2,929,243	2.88	3.45	3.47
West Virginia	12,000	14,100	16,500	723,140	747,677	762,573	1.66	1.89	2.16
Wisconsin	52,500	54,000	53,200	2,738,522	2,840,345	2,801,777	1.92	1.90	1.90
Wyoming	6,400	5,700	4,800	243,152	238,520	249,323	2.63	2.39	1.93
Puerto Rico	NA	NA	NA	1,074,411	1,131,925	1,148,959	NA	NA	NA

NA not available

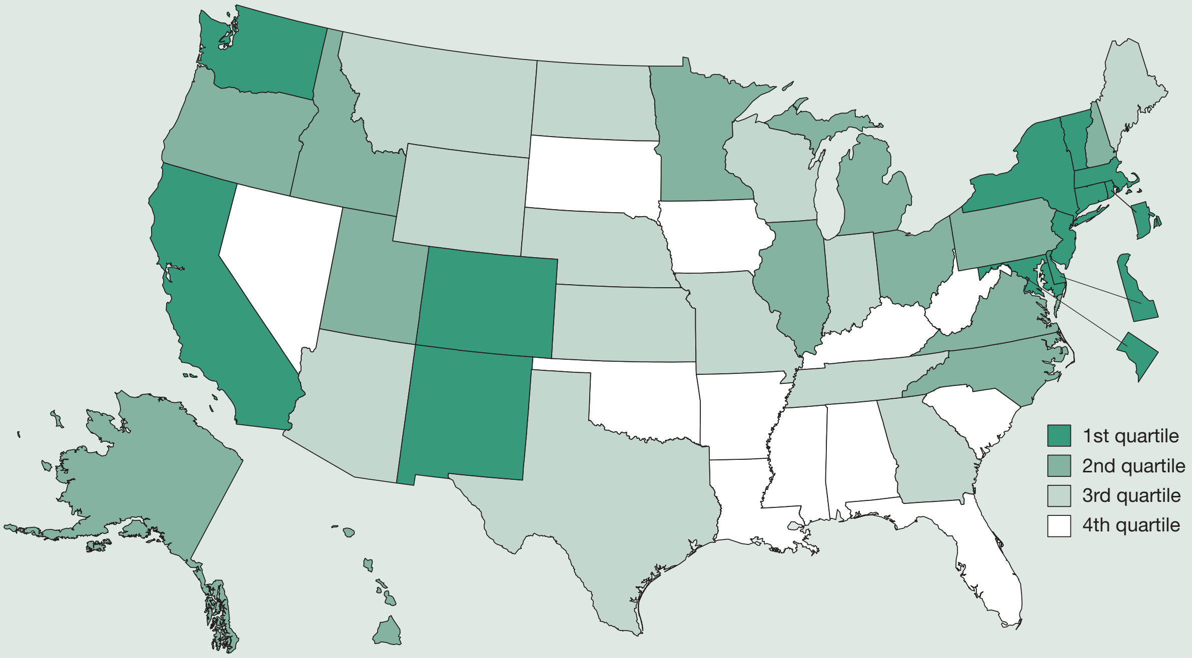
NOTES: The state total for each year is the sum of the 50 states and the District of Columbia. Scientists and engineers in an S&E occupation include people who are employed in S&E at the time of survey and are included in one of the following groups: (1) have ever received a bachelor's degree or higher in an S&E field or (2) have a non-S&E bachelor's or higher degree and were in an S&E occupation at the time of the 1993 Scientists and Engineers Statistical Data System (SESTAT) surveys. S&E occupations include mathematical, computer, life, physical, and social scientists; engineers; and postsecondary teachers in any of the S&E degree fields. Workforce represents the employed component of the civilian labor force and is reported as annual data, not seasonally adjusted. Because SESTAT survey sample design does not include geography, reliability of estimates for some states may be poor because of small sample size.

SOURCES: National Science Foundation, Division of Science Resources Statistics, SESTAT; and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics.

Science & Engineering Indicators – 2004

S&E Doctorate Holders as Share of Workforce

Figure 8-11
Quartile groups for S&E doctorate holders as share of workforce: 2001



1st quartile (4.85–0.50 percent)	2nd quartile (0.49–0.34 percent)	3rd quartile (0.33–0.29 percent)	4th quartile (0.28–0.19 percent)
California	Alaska	Arizona	Alabama
Colorado	Hawaii	Georgia	Arkansas
Connecticut	Idaho	Indiana	Florida
Delaware	Illinois	Kansas	Iowa
District of Columbia	Michigan	Maine	Kentucky
Maryland	Minnesota	Missouri	Louisiana
Massachusetts	New Hampshire	Montana	Mississippi
New Jersey	North Carolina	Nebraska	Nevada
New Mexico	Ohio	North Dakota	Oklahoma
New York	Oregon	Tennessee	South Carolina
Rhode Island	Pennsylvania	Texas	South Dakota
Vermont	Utah	Wisconsin	West Virginia
Washington	Virginia	Wyoming	

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients; and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics. See table 8-11.

This indicator shows a state's tendency to attract and retain highly trained scientists and engineers. Such people often conduct research and development, manage R&D activities, or are otherwise engaged in knowledge-intensive activities. A high value for this indicator suggests employment opportunities in a state for individuals with highly advanced S&E training.

S&E includes physical, earth, ocean, atmospheric, life, computer, and social sciences; mathematics; engineering; and psychology. S&E doctorate holders exclude those with doctorates from foreign institutions. The location of the doctorate holders primarily reflects where the individuals work. Civilian workforce data are Bureau of Labor Statistics estimates based on the Current Population Survey, with location based on residence. Because of this difference and the sample-based nature of the data, estimates for sparsely populated states and the District of Columbia may be imprecise.

Findings

- In 2001, fewer than 0.5 percent of the workforce held an S&E doctorate, little changed from 1993.
- Although the number of employed S&E doctorate holders increased by 24 percent from 1993 to 2001, the size of the total workforce rose at nearly the same rate.
- States in the top quartile tend to be home to major research laboratories, research universities, or research-intensive industries.
- The District of Columbia is an outlier.

Table 8-11

S&E doctorate holders as share of workforce, by state: 1993, 1997, and 2001

	S&E doctorate holders			Workforce			S&E doctorate holders in workforce (percent)		
State	1993	1997	2001	1993	1997	2001	1993	1997	2001
All states	461,210	516,580	572,820	120,303,214	129,540,407	137,237,739	0.38	0.40	0.42
Alabama	5,020	6,610	5,330	1,845,425	2,057,160	2,022,294	0.27	0.32	0.26
Alaska	1,050	1,110	1,200	274,788	289,735	299,140	0.38	0.38	0.40
Arizona	5,040	6,280	7,070	1,715,112	2,080,658	2,458,074	0.29	0.30	0.29
Arkansas	1,770	2,320	2,560	1,092,878	1,147,974	1,185,171	0.16	0.20	0.22
California	60,490	70,490	80,870	13,918,275	14,942,526	16,260,126	0.43	0.47	0.50
Colorado	8,890	10,740	11,780	1,800,035	2,080,012	2,290,554	0.49	0.52	0.51
Connecticut	7,510	8,770	9,490	1,672,617	1,634,771	1,697,977	0.45	0.54	0.56
Delaware	3,500	3,710	3,540	354,352	365,650	414,383	0.99	1.01	0.85
District of Columbia	13,510	11,800	14,200	280,873	237,189	292,531	4.81	4.97	4.85
Florida	11,770	13,330	15,740	6,191,793	6,780,081	7,638,800	0.19	0.20	0.21
Georgia	8,130	9,880	11,990	3,265,259	3,727,295	4,053,118	0.25	0.27	0.30
Hawaii	2,360	2,550	2,580	560,898	556,673	564,187	0.42	0.46	0.46
Idaho	1,860	2,030	2,230	513,653	600,465	647,043	0.36	0.34	0.34
Illinois	19,160	21,260	22,110	5,570,146	5,912,684	6,124,677	0.34	0.36	0.36
Indiana	7,610	7,570	9,580	2,785,578	2,978,607	2,997,804	0.27	0.25	0.32
Iowa	3,790	4,120	4,390	1,497,084	1,527,935	1,571,730	0.25	0.27	0.28
Kansas	3,290	3,770	3,970	1,256,952	1,326,289	1,323,950	0.26	0.28	0.30
Kentucky	3,570	4,110	4,590	1,689,935	1,812,779	1,878,273	0.21	0.23	0.24
Louisiana	5,230	5,360	5,290	1,746,168	1,889,133	1,930,874	0.30	0.28	0.27
Maine	1,830	2,150	1,990	582,047	625,790	658,478	0.31	0.34	0.30
Maryland	18,390	21,020	22,730	2,505,102	2,640,878	2,727,116	0.73	0.80	0.83
Massachusetts	21,360	23,330	29,100	2,945,402	3,130,763	3,268,262	0.73	0.75	0.89
Michigan	13,020	15,060	17,380	4,418,025	4,752,196	4,886,276	0.29	0.32	0.36
Minnesota	8,030	9,810	11,410	2,349,196	2,537,651	2,782,644	0.34	0.39	0.41
Mississippi	2,750	3,000	3,170	1,138,166	1,189,825	1,233,922	0.24	0.25	0.26
Missouri	7,970	9,490	9,280	2,489,049	2,768,598	2,879,250	0.32	0.34	0.32
Montana	1,460	1,690	1,440	400,259	430,261	441,972	0.36	0.39	0.33
Nebraska	2,380	3,010	2,890	835,581	881,901	923,481	0.28	0.34	0.31
Nevada	1,380	1,620	2,030	689,404	846,319	1,044,918	0.20	0.19	0.19
New Hampshire	1,990	2,230	2,470	575,418	625,386	675,516	0.35	0.36	0.37
New Jersey	19,320	20,440	22,740	3,690,762	3,976,900	4,124,564	0.52	0.51	0.55
New Mexico	6,320	7,480	7,750	697,828	763,254	819,755	0.91	0.98	0.95
New York	39,110	40,080	43,990	7,973,256	8,276,305	8,688,691	0.49	0.48	0.51
North Carolina	12,220	13,730	16,760	3,380,985	3,702,936	3,971,115	0.36	0.37	0.42
North Dakota	1,200	1,350	1,080	306,234	338,691	335,951	0.39	0.40	0.32
Ohio	16,700	18,700	20,070	5,130,907	5,452,225	5,595,965	0.33	0.34	0.36
Oklahoma	4,410	4,580	4,360	1,435,793	1,529,590	1,607,037	0.31	0.30	0.27
Oregon	5,600	6,210	7,040	1,479,939	1,626,986	1,701,685	0.38	0.38	0.41
Pennsylvania	21,990	23,940	26,140	5,470,346	5,666,669	5,920,292	0.40	0.42	0.44
Rhode Island	2,060	2,450	2,640	471,628	475,819	521,996	0.44	0.51	0.51
South Carolina	4,310	4,780	5,130	1,686,920	1,844,062	1,847,944	0.26	0.26	0.28
South Dakota	930	1,060	1,000	348,461	374,362	397,752	0.27	0.28	0.25
Tennessee	7,660	8,520	8,990	2,356,704	2,564,781	2,733,441	0.33	0.33	0.33
Texas	25,880	28,570	32,490	8,503,521	9,309,966	10,048,069	0.30	0.31	0.32
Utah	3,720	4,800	4,820	879,788	1,006,997	1,110,359	0.42	0.48	0.43
Vermont	1,500	1,760	1,750	298,748	314,053	327,614	0.50	0.56	0.53
Virginia	13,710	15,250	17,460	3,207,393	3,273,222	3,555,720	0.43	0.47	0.49
Washington	10,570	13,360	14,760	2,495,453	2,839,863	2,822,226	0.42	0.47	0.52
West Virginia	1,760	1,980	1,890	702,895	747,677	782,034	0.25	0.26	0.24
Wisconsin	7,410	8,460	8,720	2,598,025	2,840,345	2,891,294	0.29	0.30	0.30
Wyoming	720	860	840	228,158	238,520	261,694	0.32	0.36	0.32
Puerto Rico	NA	NA	NA	1,003,885	1,131,925	1,149,521	NA	NA	NA

NA not available

NOTES: The state total for each year is the sum of the 50 states and the District of Columbia. The Survey of Doctorate Recipients sample design does not include geography. Data on S&E doctorate holders are classified by employment location and workforce data based on respondents' residence. Thus, reliability of data for areas with smaller populations is lower than for more populous states. Workforce represents the employed component of the civilian labor force and is reported as annual data, not seasonally adjusted.

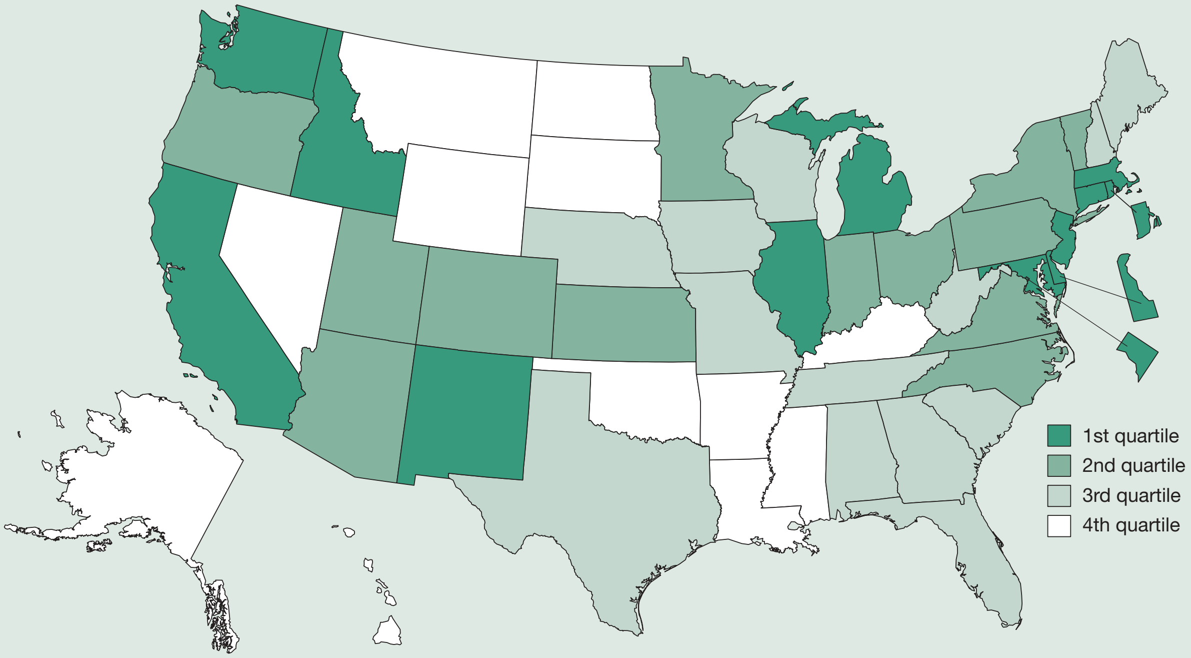
SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients; and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics.

Science & Engineering Indicators – 2004

R&D as Share of Gross State Product

Figure 8-12

Quartile groups for R&D as share of GSP: 2000



1st quartile (5.87–2.74 percent)	2nd quartile (2.57–1.68 percent)	3rd quartile (1.64–0.79 percent)	4th quartile (0.79–0.32 percent)
California	Arizona	Alabama	Alaska
Connecticut	Colorado	Florida	Arkansas
Delaware	Indiana	Georgia	Hawaii
District of Columbia	Kansas	Iowa	Kentucky
Idaho	Minnesota	Maine	Louisiana
Illinois	New York	Missouri	Mississippi
Maryland	North Carolina	Nebraska	Montana
Massachusetts	Ohio	New Hampshire	Nevada
Michigan	Oregon	South Carolina	North Dakota
New Jersey	Pennsylvania	Tennessee	Oklahoma
New Mexico	Utah	Texas	South Dakota
Rhode Island	Vermont	West Virginia	Wyoming
Washington	Virginia	Wisconsin	

SOURCES: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources;* U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data; and Government of Puerto Rico, Office of the Governor. See table 8-12.

This indicator shows the extent to which research and development play a role in a state's economy. A high value indicates that the state has a high intensity of R&D activity that may support future growth in knowledge-based industries.

R&D refers to R&D activities performed by Federal agencies, industry, universities, and other nonprofit organizations. Data for the value of gross state product (GSP) and for R&D expenditures are shown in current dollars.

Findings

- In 2000, R&D accounted for about 2.5 percent of U.S. gross domestic product, fluctuating in the 2.4–2.7 percent range over the past decade.
- Although the state distribution on this indicator bears some similarity to that of doctoral-level scientists and engineers in the workforce, it also reflects the different costs associated with different types of R&D.
- Changes in both R&D projects and GSP growth trends affect this indicator, especially for small state economies or states with large research facilities. In fact, some states experienced considerable shifts in R&D intensity over the decade, as measured by this indicator.

Table 8-12
R&D as share of GSP, by state: 1991, 1995, and 2000

	R&D performed (thousands of dollars)			GSP (millions of dollars)			R&D performed/GSP		
State	1991	1995	2000	1991	1995	2000	1991	1995	2000
All states	160,521,000	177,166,037	244,855,083	5,895,431	7,309,513	9,891,183	2.72	2.42	2.48
Alabama	1,510,827	1,680,828	1,730,117	75,977	95,514	119,319	1.99	1.76	1.45
Alaska	146,091	163,396	196,448	22,021	24,791	28,129	0.66	0.66	0.70
Arizona	1,398,709	1,957,119	3,107,291	71,876	104,586	153,469	1.95	1.87	2.02
Arkansas	198,271	329,500	454,401	41,277	53,809	66,793	0.48	0.61	0.68
California	28,346,287	36,035,609	55,092,936	814,743	925,931	1,330,025	3.48	3.89	4.14
Colorado	NA	2,700,684	4,229,501	79,448	109,021	169,341	NA	2.48	2.50
Connecticut	1,917,105	4,310,652	4,888,469	100,395	118,645	161,929	1.91	3.63	3.02
Delaware	NA	1,148,632	1,532,130	22,169	27,575	37,247	NA	4.17	4.11
District of Columbia	1,736,670	3,128,187	2,296,233	42,240	48,408	59,963	4.11	6.46	3.83
Florida	3,699,966	5,222,709	4,662,727	269,845	344,771	471,623	1.37	1.51	0.99
Georgia	1,478,861	2,112,474	2,796,192	148,722	203,505	295,539	0.99	1.04	0.95
Hawaii	144,656	169,252	291,409	34,002	37,243	42,524	0.43	0.45	0.69
Idaho	NA	913,961	1,433,567	18,655	27,155	36,755	NA	3.37	3.90
Illinois	6,413,236	7,482,753	12,767,496	285,719	359,451	466,312	2.24	2.08	2.74
Indiana	2,346,791	3,162,376	3,252,494	114,188	148,447	189,778	2.06	2.13	1.71
Iowa	777,130	1,391,005	1,017,300	57,698	71,687	89,654	1.35	1.94	1.13
Kansas	NA	763,702	1,420,089	53,576	64,069	84,526	NA	1.19	1.68
Kentucky	316,616	593,797	866,052	70,834	91,472	117,233	0.45	0.65	0.74
Louisiana	453,098	422,967	626,793	95,918	112,157	144,984	0.47	0.38	0.43
Maine	NA	345,449	318,726	23,635	27,987	36,276	NA	1.23	0.88
Maryland	5,736,048	6,865,287	8,633,558	117,630	139,495	185,049	4.88	4.92	4.67
Massachusetts	8,565,279	9,969,508	13,004,427	161,517	197,469	283,072	5.30	5.05	4.59
Michigan	8,850,565	13,274,875	18,892,070	194,230	254,179	323,717	4.56	5.22	5.84
Minnesota	2,227,672	3,087,438	4,298,967	103,923	131,841	186,097	2.14	2.34	2.31
Mississippi	302,380	314,710	512,789	41,311	54,562	66,162	0.73	0.58	0.78
Missouri	NA	2,498,360	2,583,036	110,396	139,547	177,104	NA	1.79	1.46
Montana	NA	119,109	169,856	14,075	17,537	21,702	NA	0.68	0.78
Nebraska	210,756	335,930	438,996	35,482	44,084	55,649	0.59	0.76	0.79
Nevada	261,232	445,028	377,412	33,665	49,377	75,533	0.78	0.90	0.50
New Hampshire	NA	597,697	775,004	24,948	32,388	47,385	NA	1.85	1.64
New Jersey	8,777,671	9,128,185	13,133,222	224,307	271,435	357,453	3.91	3.36	3.67
New Mexico	2,589,385	3,295,475	3,085,199	30,862	42,170	52,592	8.39	7.81	5.87
New York	10,315,493	10,954,561	13,555,586	504,665	597,593	798,382	2.04	1.83	1.70
North Carolina	1,965,076	3,191,790	5,045,250	147,473	194,634	272,934	1.33	1.64	1.85
North Dakota	NA	97,606	145,671	11,634	14,529	18,556	NA	0.67	0.79
Ohio	5,975,241	5,314,554	7,661,540	235,876	295,668	370,617	2.53	1.80	2.07
Oklahoma	604,019	528,764	659,684	59,698	69,960	90,942	1.01	0.76	0.73
Oregon	600,175	1,088,654	2,116,232	60,602	81,092	121,383	0.99	1.34	1.74
Pennsylvania	7,620,947	6,918,955	9,841,912	260,591	318,765	399,488	2.92	2.17	2.46
Rhode Island	484,693	896,570	1,500,828	21,758	25,703	36,086	2.23	3.49	4.16
South Carolina	594,444	996,261	1,126,164	68,776	86,880	112,197	0.86	1.15	1.00
South Dakota	32,297	54,667	84,801	14,093	18,257	23,452	0.23	0.30	0.36
Tennessee	1,142,486	1,394,231	2,057,293	102,049	136,821	177,401	1.12	1.02	1.16
Texas	6,635,249	8,384,534	11,552,437	403,286	513,882	738,270	1.65	1.63	1.56
Utah	664,474	1,144,080	1,360,644	33,658	46,290	68,430	1.97	2.47	1.99
Vermont	NA	308,180	465,349	11,771	13,974	18,124	NA	2.21	2.57
Virginia	2,775,919	3,897,444	5,069,481	153,965	188,963	260,837	1.80	2.06	1.94
Washington	3,889,660	5,240,679	10,516,331	122,453	151,265	218,095	3.18	3.46	4.82
West Virginia	NA	475,040	457,128	29,331	36,315	40,926	NA	1.31	1.12
Wisconsin	1,573,365	2,226,046	2,692,876	104,918	133,694	173,016	1.50	1.67	1.56
Wyoming	41,037	86,767	60,969	13,550	14,920	19,113	0.30	0.58	0.32
Puerto Rico	NA	NA	NA	22,809	28,452	41,366	NA	NA	NA

GSP gross state product
NA not available

NOTES: The state total for R&D in 1991 is based on the reported value for the nation in *National Patterns of R&D Resources 1998,* table B-1A. 1995 and 2000 R&D are based on the sum of the 50 states plus the District of Columbia. Total R&D includes R&D performed by Federal agencies, industry, universities, and other nonprofit organizations. The GSP total for each year is the sum of the 50 states and the District of Columbia. Total R&D and GSP are reported in current dollars.

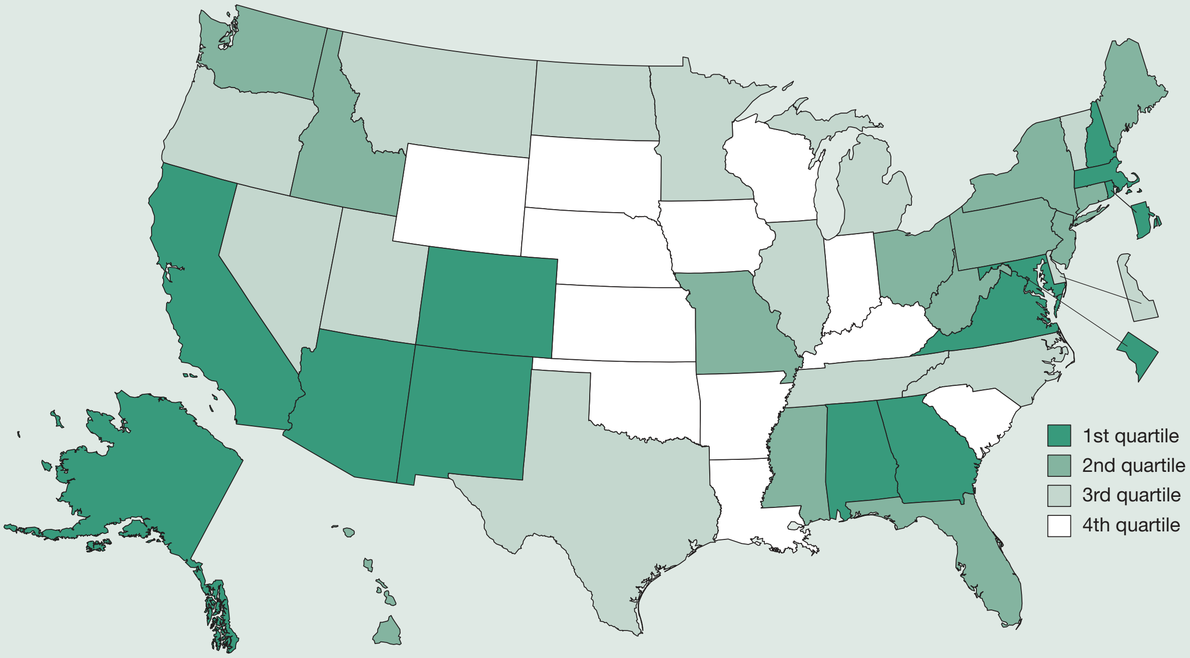
SOURCES: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* various years; U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data; and Government of Puerto Rico, Office of the Governor.

Science & Engineering Indicators – 2004

Federal R&D Obligations per Civilian Worker

Figure 8-13

Quartile groups for Federal R&D obligations per civilian worker: 2000



1st quartile ($8,113–$471)	2nd quartile ($469–$295)	3rd quartile ($289–$175)	4th quartile ($173–$96)
Alabama	Connecticut	Delaware	Arkansas
Alaska	Florida	Illinois	Indiana
Arizona	Hawaii	Michigan	Iowa
California	Idaho	Minnesota	Kansas
Colorado	Maine	Montana	Kentucky
District of Columbia	Mississippi	Nevada	Louisiana
Georgia	Missouri	North Carolina	Nebraska
Maryland	New Jersey	North Dakota	Oklahoma
Massachusetts	New York	Oregon	South Carolina
New Hampshire	Ohio	Tennessee	South Dakota
New Mexico	Pennsylvania	Texas	Wisconsin
Rhode Island	Washington	Utah	Wyoming
Virginia	West Virginia	Vermont	

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development;* and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics. See table 8-13.

This indicator shows how Federal research and development funding is disbursed geographically relative to the size of states' civilian workforces. Federal R&D funding is largely for development, but it may provide direct and indirect benefits to a state's economy and may stimulate the conduct of basic research. A high value for this indicator may indicate the existence of major federally funded R&D facilities or the presence of large defense contractors in the state.

Federal R&D dollars are counted where they are obligated; they may be expended in many locations. Civilian workforce data are Bureau of Labor Statistics estimates based on the Current Population Survey, with location based on residence. Because of these differences and the sample-based nature of the population data, estimates for sparsely populated states and the District of Columbia may be imprecise.

Findings

- Federal Government obligations to the states totaled $63.8 billion in 1992, $66.1 billion in 1996, and $71.0 billion in 2000 for R&D.
- Per civilian worker, this yielded a declining average over the period—$538 at the beginning of the period to $519 in 2000—because the workforce grew faster than Federal R&D funding.
- The state-by-state picture is marked by many sharp increases and decreases over the decade, reflecting both changes in jobs and changes in the level of Federal R&D funds.
- A high score is evident for states in the national capital area. Overall, the distribution of funds is highly skewed, with only 11 states above the state average.

Table 8-13
Federal R&D obligations per civilian worker, by state: 1992, 1996, and 2000

	Federal R&D obligations (thousands of dollars)			Civilian workers			Federal R&D obligations per civilian worker (dollars)		
State	1992	1996	2000	1992	1996	2000	1992	1996	2000
All states	63,818,372	66,071,314	71,034,535	118,534,413	126,902,959	136,927,182	538	521	519
Alabama	2,151,670	2,178,776	1,614,901	1,816,751	1,990,992	2,042,827	1,184	1,094	791
Alaska	92,966	93,334	146,777	261,155	288,511	297,455	356	324	493
Arizona	638,209	706,673	1,121,701	1,673,329	2,087,744	2,381,921	381	338	471
Arkansas	68,848	148,166	116,333	1,069,498	1,164,104	1,207,006	64	127	96
California	15,999,143	12,658,120	14,082,960	13,973,304	14,391,485	16,048,937	1,145	880	878
Colorado	1,479,238	1,277,553	1,369,733	1,710,242	2,004,741	2,286,203	865	637	599
Connecticut	578,332	798,866	806,228	1,680,758	1,619,809	1,743,504	344	493	462
Delaware	43,065	64,865	69,867	346,265	363,315	399,874	124	179	175
District of Columbia	2,185,196	2,574,139	2,374,647	283,586	247,800	292,704	7,706	10,388	8,113
Florida	2,832,290	2,957,866	2,216,206	6,015,795	6,603,424	7,520,377	471	448	295
Georgia	2,512,567	4,137,785	2,632,186	3,119,071	3,566,542	4,094,668	806	1,160	643
Hawaii	150,654	147,574	209,737	557,430	555,747	566,142	270	266	370
Idaho	299,457	244,579	216,928	497,343	584,873	624,829	602	418	347
Illinois	921,924	1,094,284	1,404,613	5,561,305	5,839,807	6,243,968	166	187	225
Indiana	367,003	439,766	506,326	2,652,386	2,938,752	3,020,326	138	150	168
Iowa	194,674	213,370	267,038	1,440,385	1,533,334	1,547,772	135	139	173
Kansas	91,235	212,035	223,493	1,255,435	1,287,825	1,357,420	73	165	165
Kentucky	71,706	78,597	203,851	1,644,594	1,759,772	1,907,096	44	45	107
Louisiana	169,580	228,730	249,045	1,776,772	1,863,250	1,918,716	95	123	130
Maine	60,568	56,711	249,812	603,803	631,965	664,487	100	90	376
Maryland	5,779,695	6,730,700	8,684,796	2,497,600	2,651,542	2,682,600	2,314	2,538	3,237
Massachusetts	3,227,932	3,192,130	4,145,472	2,875,809	3,034,989	3,230,169	1,122	1,052	1,283
Michigan	876,267	707,914	975,052	4,273,741	4,658,776	4,989,288	205	152	195
Minnesota	456,392	679,503	781,132	2,289,419	2,499,522	2,704,989	199	272	289
Mississippi	255,695	250,633	394,585	1,093,688	1,180,215	1,260,277	234	212	313
Missouri	733,542	1,267,840	890,597	2,515,450	2,772,003	2,867,751	292	457	311
Montana	71,548	63,042	95,025	392,556	422,434	452,860	182	149	210
Nebraska	71,143	88,454	98,491	813,076	883,284	917,042	87	100	107
Nevada	465,781	253,235	263,897	666,348	794,455	1,016,210	699	319	260
New Hampshire	156,135	268,476	356,873	564,565	597,195	672,536	277	450	531
New Jersey	1,646,784	1,272,576	1,937,769	3,690,214	3,878,434	4,128,649	446	328	469
New Mexico	2,211,251	1,954,981	2,130,504	688,763	733,625	812,347	3,210	2,665	2,623
New York	3,058,737	2,504,851	2,927,523	7,911,253	8,075,708	8,775,663	387	310	334
North Carolina	700,671	821,457	1,062,536	3,334,507	3,618,202	3,995,484	210	227	266
North Dakota	54,230	46,178	64,051	298,437	333,616	334,773	182	138	191
Ohio	1,863,371	1,681,723	1,799,136	5,094,796	5,364,743	5,529,904	366	313	325
Oklahoma	126,054	138,258	185,121	1,433,459	1,511,991	1,601,248	88	91	116
Oregon	226,514	308,179	468,167	1,429,496	1,616,125	1,733,280	158	191	270
Pennsylvania	1,794,428	1,921,246	2,357,552	5,439,531	5,587,310	5,833,113	330	344	404
Rhode Island	386,339	583,158	418,037	474,214	468,284	520,809	815	1,245	803
South Carolina	172,130	186,659	248,988	1,682,743	1,753,247	1,900,817	102	106	131
South Dakota	23,886	35,041	38,803	341,854	379,898	397,873	70	92	98
Tennessee	666,025	558,572	734,406	2,297,758	2,602,672	2,720,964	290	215	270
Texas	2,872,956	3,493,457	2,671,790	8,308,202	9,129,997	9,950,535	346	383	269
Utah	313,996	351,719	285,968	821,434	976,817	1,105,951	382	360	259
Vermont	51,314	47,089	72,030	289,515	308,887	324,171	177	152	222
Virginia	3,231,339	4,576,317	4,842,811	3,180,803	3,241,326	3,524,677	1,016	1,412	1,374
Washington	900,492	1,152,903	1,329,466	2,446,615	2,691,616	2,891,456	368	428	460
West Virginia	166,380	254,384	235,677	686,570	744,945	765,132	242	341	308
Wisconsin	307,651	331,373	420,839	2,537,534	2,823,966	2,862,683	121	117	147
Wyoming	41,369	37,477	35,059	225,256	243,343	257,699	184	154	136
Puerto Rico	NA	51,614	81,016	986,778	1,112,474	1,173,795	NA	46	69

NA not available

NOTES: The state total for each year is the sum of the 50 states and the District of Columbia. Only the following 10 agencies were required to report Federal R&D obligations: the Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, the Interior, and Transportation; the Environmental Protection Agency; the National Aeronautics and Space Administration; and the National Science Foundation. These obligations represent approximately 98 percent of total Federal R&D obligations in FY 1992, 1996, and 2000. Civilian workers represent the employed component of the civilian labor force and are reported as annual data, not seasonally adjusted.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development,* various years; and U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistics.

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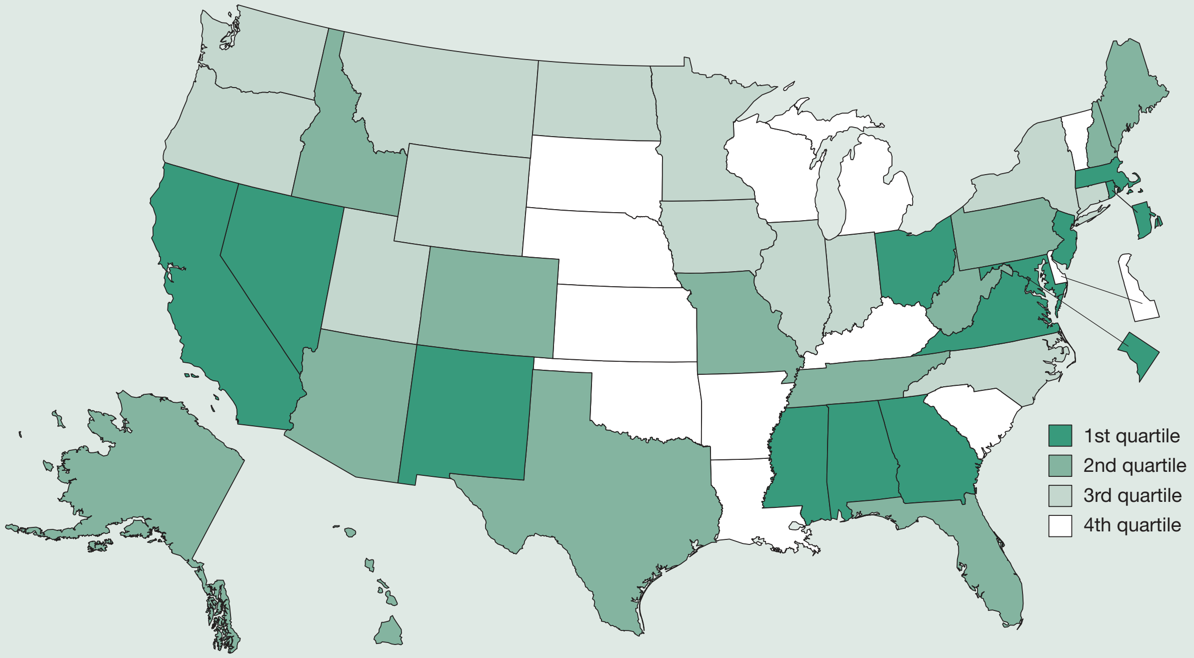
Federal R&D Obligations per Individual in S&E Occupation

Figure 8-14
Quartile groups for Federal R&D obligations per individual in S&E occupation: 1999



1st quartile ($77,756–$21,031)	2nd quartile ($20,053–$12,947)	3rd quartile ($12,874–$7,337)	4th quartile ($7,102–$3,206)
Alabama	Alaska	Connecticut	Arkansas
California	Arizona	Illinois	Delaware
District of Columbia	Colorado	Indiana	Kansas
Georgia	Florida	Iowa	Kentucky
Maryland	Hawaii	Minnesota	Louisiana
Massachusetts	Idaho	Montana	Michigan
Mississippi	Maine	New York	Nebraska
Nevada	Missouri	North Carolina	Oklahoma
New Jersey	New Hampshire	North Dakota	South Carolina
New Mexico	Pennsylvania	Oregon	South Dakota
Ohio	Tennessee	Utah	Vermont
Rhode Island	Texas	Washington	Wisconsin
Virginia	West Virginia	Wyoming	

SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), *Federal Funds for Research and Development;* and NSF/SRS, Scientists and Engineers Statistical Data System (SESTAT). See table 8-14.

This indicator demonstrates how Federal research and development obligations are distributed geographically based on individuals with a bachelor's or higher degree who work in science and engineering occupations. These positions include mathematical, computer, life, physical, and social scientists; engineers; and postsecondary teachers in any of these S&E fields. Positions such as managers and elementary and secondary school teachers are excluded.

Federal R&D dollars are counted where they are obligated but may be expended in many locations. Data on people in S&E occupations are sample based. For these reasons, estimates for sparsely populated states and the District of Columbia may be imprecise. A high value for this indicator may indicate the existence of major federally funded R&D facilities or the presence of large defense contractors in the state.

Findings

- The Federal Government obligated about $66.5 billion to the states in 1995, $68.4 billion in 1997, and $73.6 billion in 1999 for R&D.
- The number of people in S&E occupations grew at about the same rate as the Federal R&D obligations, yielding a fairly stable amount per person during this period, about $20,900 in 1999.
- Changes in state-by-state distribution of Federal R&D obligations resulted in significant changes in per-person funds for several states.
- A high score was evident for states in the national capital area. The state distribution on this indicator is highly skewed, with only 13 states above the national average.

Table 8-14
Federal R&D obligations per individual in S&E occupation, by state: 1995, 1997, and 1999

State	Federal R&D obligations (thousands of dollars)			Individuals in S&E occupations			Federal R&D obligations per individual in S&E occupation (dollars)		
	1995	1997	1999	1995	1997	1999	1995	1997	1999
All states	66,485,615	68,362,301	73,645,266	3,178,000	3,357,000	3,525,100	20,921	20,364	20,892
Alabama	1,931,323	2,213,683	1,806,956	40,800	44,300	43,300	47,336	49,970	41,731
Alaska	96,924	99,928	115,015	6,600	6,300	7,700	14,685	15,862	14,937
Arizona	902,338	732,065	1,116,946	47,400	54,000	55,700	19,037	13,557	20,053
Arkansas	97,702	95,296	106,422	14,100	15,300	16,900	6,929	6,228	6,297
California	12,600,156	13,730,886	15,600,123	463,900	478,000	492,000	27,161	28,726	31,708
Colorado	1,049,208	1,340,231	1,438,682	82,700	88,500	96,900	12,687	15,144	14,847
Connecticut	900,719	846,458	655,191	56,900	53,300	57,500	15,830	15,881	11,395
Delaware	57,746	48,964	52,255	14,300	15,700	16,300	4,038	3,119	3,206
District of Columbia	2,755,369	2,232,284	2,451,606	53,200	51,300	53,900	51,793	43,514	45,484
Florida	2,391,836	3,326,418	2,284,405	105,500	116,600	123,000	22,671	28,528	18,572
Georgia	4,366,021	3,919,868	2,023,240	69,800	75,600	85,900	62,550	51,850	23,553
Hawaii	139,291	150,722	198,808	13,100	11,500	11,700	10,633	13,106	16,992
Idaho	210,964	205,660	200,672	13,200	13,900	15,500	15,982	14,796	12,947
Illinois	1,107,430	1,140,163	1,316,085	138,300	148,600	155,200	8,007	7,673	8,480
Indiana	426,330	410,398	413,864	51,300	54,000	56,000	8,311	7,600	7,390
Iowa	212,096	228,180	264,060	22,100	24,500	23,900	9,597	9,313	11,049
Kansas	120,388	255,490	191,603	29,500	34,300	31,400	4,081	7,449	6,102
Kentucky	73,079	91,291	146,845	22,700	23,100	26,100	3,219	3,952	5,626
Louisiana	170,087	211,036	219,218	35,900	36,200	35,500	4,738	5,830	6,175
Maine	53,075	68,683	150,569	7,900	11,600	11,200	6,718	5,921	13,444
Maryland	7,343,723	7,328,787	8,094,369	93,300	93,900	104,100	78,711	78,049	77,756
Massachusetts	3,337,816	3,437,516	3,129,401	130,900	136,600	148,800	25,499	25,165	21,031
Michigan	683,187	735,059	839,757	116,700	122,900	131,800	5,854	5,981	6,371
Minnesota	570,248	609,395	885,141	69,400	76,800	81,600	8,217	7,935	10,847
Mississippi	209,714	289,791	351,571	15,700	14,100	16,100	13,358	20,553	21,837
Missouri	1,606,215	1,130,148	928,681	53,100	59,700	61,000	30,249	18,930	15,224
Montana	63,810	79,347	95,446	8,100	10,200	8,600	7,878	7,779	11,098
Nebraska	84,680	82,981	94,089	15,300	15,200	19,900	5,535	5,459	4,728
Nevada	368,914	295,042	279,129	11,600	10,100	10,800	31,803	29,212	25,845
New Hampshire	213,243	278,697	291,723	14,000	17,000	19,100	15,232	16,394	15,273
New Jersey	1,297,664	1,318,793	2,661,153	118,900	118,500	121,200	10,914	11,129	21,957
New Mexico	1,959,948	1,933,123	2,068,291	25,100	25,900	28,600	78,086	74,638	72,318
New York	2,585,904	2,471,013	2,689,016	197,400	206,900	216,000	13,100	11,943	12,449
North Carolina	831,620	900,344	1,007,518	75,000	84,500	93,800	11,088	10,655	10,741
North Dakota	47,359	53,015	59,947	4,500	4,300	4,700	10,524	12,329	12,755
Ohio	1,809,958	1,879,784	3,687,855	119,900	138,600	132,900	15,096	13,563	27,749
Oklahoma	158,691	160,356	165,818	25,500	28,600	28,100	6,223	5,607	5,901
Oregon	283,411	319,587	408,099	37,800	39,800	43,400	7,498	8,030	9,403
Pennsylvania	2,394,246	1,893,723	1,907,139	137,700	141,800	143,300	17,387	13,355	13,309
Rhode Island	514,632	403,844	391,717	15,600	13,500	14,200	32,989	29,914	27,586
South Carolina	173,217	166,607	215,941	31,800	34,200	37,500	5,447	4,872	5,758
South Dakota	26,501	41,955	38,951	5,400	5,400	7,000	4,908	7,769	5,564
Tennessee	582,499	566,242	684,712	50,400	47,100	44,400	11,558	12,022	15,421
Texas	4,068,928	3,640,162	3,853,339	229,600	232,300	254,800	17,722	15,670	15,123
Utah	368,829	319,851	305,019	26,100	24,400	25,200	14,131	13,109	12,104
Vermont	52,950	49,885	61,707	8,800	10,200	12,500	6,017	4,891	4,937
Virginia	3,392,184	4,849,753	5,750,372	104,500	116,200	124,100	32,461	41,736	46,337
Washington	1,131,625	1,226,154	1,306,757	75,800	97,900	101,500	14,929	12,525	12,874
West Virginia	287,939	193,061	227,023	12,000	14,100	16,500	23,995	13,692	13,759
Wisconsin	338,475	332,214	377,801	52,500	54,000	53,200	6,447	6,152	7,102
Wyoming	35,403	28,368	35,219	6,400	5,700	4,800	5,532	4,977	7,337
Puerto Rico	46,695	58,943	72,709	NA	NA	NA	NA	NA	NA

NA not available

NOTES: The state total for each year is the sum of the 50 states and the District of Columbia. Only the following 10 agencies were required to report Federal R&D obligations: the Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, the Interior, and Transportation; the Environmental Protection Agency; the National Aeronautics and Space Administration; and the National Science Foundation. These obligations represent approximately 98 percent of Federal R&D obligations in FY 1995, 1997, and 1999. People in S&E occupations include those who are employed in S&E at the time of survey and are included in one of the following groups: (1) have ever received a bachelor's degree or higher in an S&E field or (2) have a non-S&E bachelor's or higher degree and were in an S&E occupation at the time of the 1993 Scientists and Engineers Statistical Data System (SESTAT) survey. S&E occupations include mathematical, computer, life, physical, and social scientists; engineers; and postsecondary teachers in any S&E degree field. Because SESTAT survey sample designs do not include geography, reliability of estimates in some states may be poor because of small sample size.

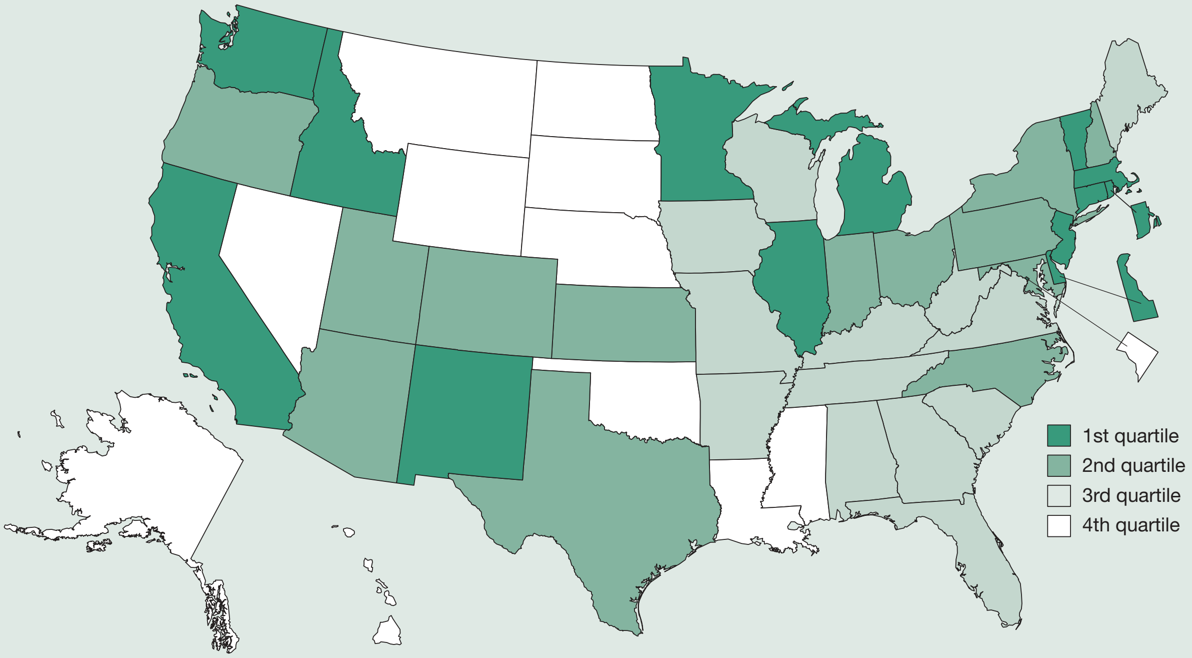
SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), *Federal Funds for Research and Development,* various years; and NSF/SRS, SESTAT.

Science & Engineering Indicators – 2004

Industry-Performed R&D as Share of Private-Industry Output

Figure 8-15

Quartile groups for industry-performed R&D as share of private-industry output: 2000



1st quartile (6.08–2.23 percent)	2nd quartile (2.18–1.33 percent)	3rd quartile (1.29–0.47 percent)	4th quartile (0.44–0.04 percent)
California	Arizona	Alabama	Alaska
Connecticut	Colorado	Arkansas	District of Columbia
Delaware	Indiana	Florida	Hawaii
Idaho	Kansas	Georgia	Louisiana
Illinois	Maryland	Iowa	Mississippi
Massachusetts	New Hampshire	Kentucky	Montana
Michigan	New York	Maine	Nebraska
Minnesota	North Carolina	Missouri	Nevada
New Jersey	Ohio	South Carolina	North Dakota
New Mexico	Oregon	Tennessee	Oklahoma
Rhode Island	Pennsylvania	Virginia	South Dakota
Vermont	Texas	West Virginia	Wyoming
Washington	Utah	Wisconsin	

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development; U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data; and European Commission, *Third European Report on Science & Technology Indicators,* 2003. See table 8-15.

This indicator measures the emphasis that private industry places on research and development. Industrial R&D focuses on projects that are expected to yield new or improved products, processes, or services and thus bring direct benefits to the company.

Differences among states on this indicator should be interpreted with caution. Because industries differ in reliance on R&D, the indicator reflects state differences in industrial structure as much as the behavior of individual companies. Furthermore, industrial R&D data for states with small economies may have high imputation rates and imprecise estimates.

Findings

- The state total of industry-performed R&D reached $187.5 billion in 2000, up from $117.0 billion in 1991.
- Throughout the period, U.S. private industry devoted 2.0–2.3 percent of its output to R&D.
- Broadly comparable figures for the European Union (1999) and Japan (1998), as reported by the European Commission, were 1.4 and 2.5 percent, respectively.
- A wide margin between top and bottom quartiles marks this indicator. Large differences among states may reflect differences in industry structure or in R&D intensities of individual firms, whereas major shifts within a state over the decade probably reflect the behavior of large firms in the state.

Table 8-15
Industry-performed R&D as share of private-industry output, by state: 1991, 1995, and 2000

	Industry-performed R&D (millions of dollars)			Private-industry output (millions of dollars)			Industry-performed R&D/ private-industry output (percent)		
State	1991	1995	2000	1991	1995	2000	1991	1995	2000
All states	116,952	130,332	187,544	5,109,484	6,384,551	8,735,491	2.29	2.04	2.15
Alabama	596	686	607	62,731	80,215	100,871	0.95	0.86	0.60
Alaska	21	30	9	17,486	19,865	22,844	0.12	0.15	0.04
Arizona	1,080	1,356	2,445	60,672	90,743	135,241	1.78	1.49	1.81
Arkansas	NA	181	273	35,790	47,231	58,328	NA	0.38	0.47
California	NA	28,710	45,769	713,723	812,793	1,188,938	NA	3.53	3.85
Colorado	NA	1,865	3,140	66,880	93,797	149,983	NA	1.99	2.09
Connecticut	1,756	3,906	4,371	90,759	107,670	148,401	1.93	3.63	2.95
Delaware	NA	1,077	1,444	20,043	24,965	33,884	NA	4.31	4.26
District of Columbia	46	672	112	25,118	28,710	38,387	0.18	2.34	0.29
Florida	NA	4,101	3,212	231,125	300,056	413,952	NA	1.37	0.78
Georgia	993	1,175	1,579	127,028	176,858	260,526	0.78	0.66	0.61
Hawaii	13	14	44	26,932	29,278	33,500	0.05	0.05	0.13
Idaho	NA	827	1,338	15,786	23,534	31,882	NA	3.51	4.20
Illinois	5,750	5,776	10,661	255,321	322,813	419,836	2.25	1.79	2.54
Indiana	2,274	2,721	2,668	101,138	133,109	170,420	2.25	2.04	1.57
Iowa	527	998	538	50,523	63,121	78,878	1.04	1.58	0.68
Kansas	NA	569	1,140	45,952	54,563	73,084	NA	1.04	1.56
Kentucky	176	452	582	60,319	78,522	101,566	0.29	0.58	0.57
Louisiana	NA	61	126	84,430	98,689	128,381	NA	0.06	0.10
Maine	NA	286	201	19,833	23,958	31,175	NA	1.19	0.64
Maryland	1,376	1,075	2,032	95,836	114,084	152,905	1.44	0.94	1.33
Massachusetts	NA	7,416	9,863	144,891	177,676	258,215	NA	4.17	3.82
Michigan	9,283	12,388	17,640	170,319	226,269	290,273	5.45	5.47	6.08
Minnesota	2,070	2,636	3,722	91,529	117,004	167,043	2.26	2.25	2.23
Mississippi	NA	66	101	34,614	46,189	55,156	NA	0.14	0.18
Missouri	NA	2,028	1,893	97,151	123,851	156,394	NA	1.64	1.21
Montana	NA	17	28	11,631	14,673	18,072	NA	0.12	0.15
Nebraska	67	150	199	29,792	37,499	47,880	0.23	0.40	0.42
Nevada	95	322	248	29,645	44,133	67,778	0.32	0.73	0.37
New Hampshire	NA	472	586	22,434	29,459	43,729	NA	1.60	1.34
New Jersey	8,933	8,200	12,062	199,895	242,564	322,959	4.47	3.38	3.73
New Mexico	1,217	1,461	1,158	24,779	34,679	43,493	4.91	4.21	2.66
New York	9,457	8,651	10,539	445,505	530,410	718,871	2.12	1.63	1.47
North Carolina	1,470	2,226	3,672	127,213	168,801	238,869	1.16	1.32	1.54
North Dakota	NA	12	51	9,551	12,155	15,851	NA	0.10	0.32
Ohio	5,406	4,001	5,962	208,508	262,644	329,722	2.59	1.52	1.81
Oklahoma	448	288	333	49,628	58,256	76,199	0.90	0.49	0.44
Oregon	NA	741	1,651	52,266	71,012	107,644	NA	1.04	1.53
Pennsylvania	NA	5,331	7,873	231,389	284,861	360,516	NA	1.87	2.18
Rhode Island	174	520	1,090	19,018	22,454	31,889	0.91	2.32	3.42
South Carolina	479	739	781	56,598	73,868	94,795	0.85	1.00	0.82
South Dakota	6	19	44	11,983	15,825	20,467	0.05	0.12	0.21
Tennessee	843	1,003	1,215	88,286	120,411	156,817	0.95	0.83	0.77
Texas	5,439	6,211	8,961	353,185	451,194	656,638	1.54	1.38	1.36
Utah	407	803	979	27,647	39,006	58,765	1.47	2.06	1.67
Vermont	NA	248	396	10,322	12,223	15,798	NA	2.03	2.51
Virginia	1,275	1,577	2,718	121,399	152,134	214,822	1.05	1.04	1.27
Washington	3,677	4,294	9,265	103,317	128,455	189,418	3.56	3.34	4.89
West Virginia	NA	243	235	25,191	31,175	34,133	NA	0.78	0.69
Wisconsin	1,304	1,706	1,981	92,687	118,355	153,785	1.41	1.44	1.29
Wyoming	2	25	7	11,686	12,742	16,518	0.02	0.20	0.04
Puerto Rico	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA not available

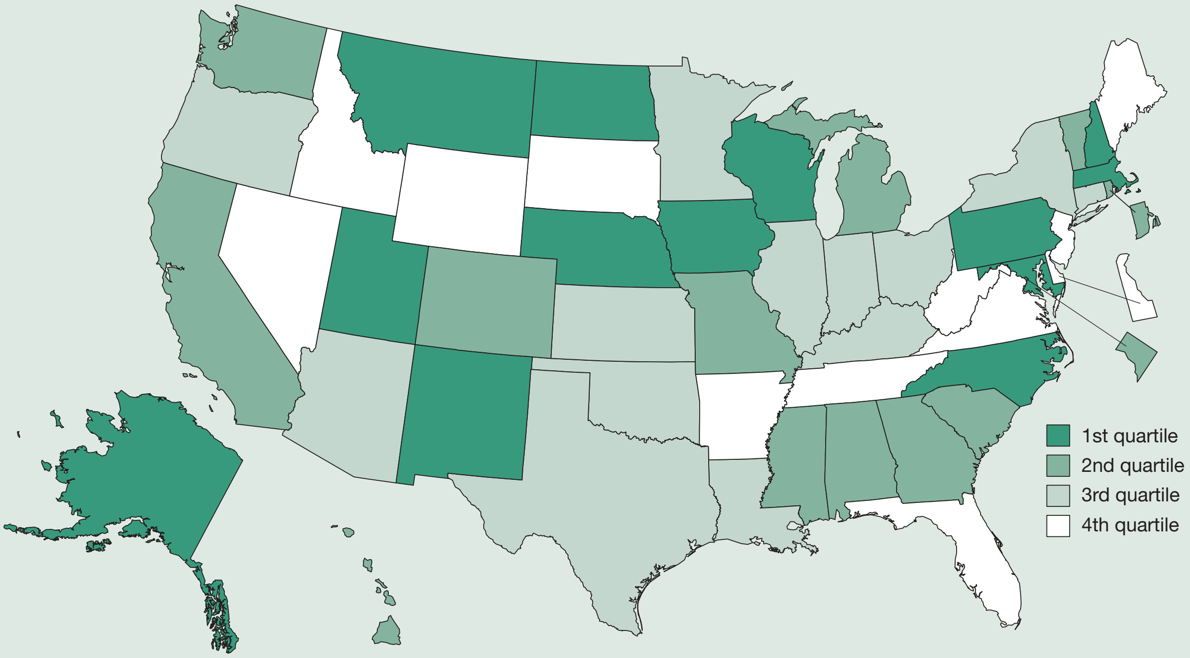
NOTES: The state total for industry-performed R&D in 1991 is based on the the reported value for the United States in the Survey of Industrial Research and Development: 2000, table A-30. The state total for industry-performed R&D in 1995 and 2000 is based on the sum of the 50 states and the District of Columbia. 1991 industry-performed R&D for Arkansas, California, Colorado, Florida, Idaho, Kansas, Louisiana, Maine, Massachusetts, Mississippi, Missouri, Montana, North Dakota, Oregon, and Pennsylvania have imputations of more than 50 percent and have been withheld. 1991 industry-performed R&D for Delaware, New Hampshire, Vermont, and West Virginia have been withheld to avoid disclosing information about individual companies. 1995 industry-performed R&D for Arizona, Delaware, District of Columbia, Illinois, Indiana, Minnesota, Missouri, Texas, and Washington have imputations of more than 50 percent. 2000 industry-performed R&D for Alaska, Connecticut, Delaware, Indiana, Kansas, Michigan, Minnesota, Montana, New Mexico, North Dakota, Rhode Island, Tennessee, and Washington have imputations of more than 50 percent. The state total for private-industry output for each year is the sum of the 50 states and the District of Columbia. Private-industry output is reported in current dollars.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development; and U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data.

Science & Engineering Indicators – 2004

Academic R&D per $1,000 of Gross State Product

Figure 8-16
Quartile groups for academic R&D per $1,000 GSP: 2001



1st quartile ($5.96–$4.04)	2nd quartile ($4.01–$3.14)	3rd quartile ($3.12–$2.47)	4th quartile ($2.32–$1.33)
Alaska	Alabama	Arizona	Arkansas
Iowa	California	Connecticut	Delaware
Maryland	Colorado	Illinois	Florida
Massachusetts	District of Columbia	Indiana	Idaho
Montana	Georgia	Kansas	Maine
Nebraska	Hawaii	Kentucky	Nevada
New Hampshire	Michigan	Louisiana	New Jersey
New Mexico	Mississippi	Minnesota	South Dakota
North Carolina	Missouri	New York	Tennessee
North Dakota	Rhode Island	Ohio	Virginia
Pennsylvania	South Carolina	Oklahoma	West Virginia
Utah	Vermont	Oregon	Wyoming
Wisconsin	Washington	Texas	

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Academic Research and Development Expenditures;* and U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data. See table 8-16.

This indicator measures the extent of spending on academic research performed in a state relative to the size of that state's economy. Academic research and development is more basic and less product oriented than R&D performed by industry. It can be a valuable precursor to future economic development. High values on this indicator may reflect an academic R&D system that can compete for funding from Federal, state, and industrial sources. In this indicator, Maryland data exclude expenditures by the Applied Physics Laboratory at the Johns Hopkins University.

Findings

- The states' academic R&D expenditures grew from $16.9 billion in 1991 to $32.2 billion in 2001.
- In 2001, academic-performed R&D accounted for 12.1 percent of R&D performed in the states.
- Although the average value of this indicator rose approximately 11 percent during the past decade, some states showed sizable increases or decreases during this period.

Table 8-16
Academic R&D per $1,000 GSP, by state: 1991, 1996 and 2001

	Academic R&D (thousands of dollars)			GSP (millions of dollars)			Academic R&D/$1,000 GSP		
State	1991	1996	2001	1991	1996	2001	1991	1996	2001
All states	16,863,363	22,136,530	32,170,317	5,895,431	7,715,898	10,137,194	2.86	2.87	3.17
Alabama	252,998	342,021	445,299	75,977	99,286	121,490	3.33	3.44	3.67
Alaska	67,432	71,381	115,601	22,021	25,774	28,581	3.06	2.77	4.04
Arizona	284,128	375,881	500,548	71,876	112,882	160,687	3.95	3.33	3.12
Arkansas	55,081	94,006	140,741	41,277	56,796	67,913	1.33	1.66	2.07
California	2,146,736	2,817,913	4,422,032	814,743	973,395	1,359,265	2.63	2.89	3.25
Colorado	260,587	406,203	572,950	79,448	117,118	173,772	3.28	3.47	3.30
Connecticut	320,935	388,134	498,745	100,395	124,157	166,165	3.20	3.13	3.00
Delaware	44,696	54,154	79,985	22,169	29,001	40,509	2.02	1.87	1.97
District of Columbia	118,398	201,445	228,110	42,240	48,505	64,459	2.80	4.15	3.54
Florida	438,054	638,102	997,048	269,845	366,318	491,488	1.62	1.74	2.03
Georgia	484,019	712,188	988,883	148,722	219,520	299,874	3.25	3.24	3.30
Hawaii	78,166	111,202	156,976	34,002	37,490	43,710	2.30	2.97	3.59
Idaho	41,437	64,930	82,496	18,655	28,101	36,905	2.22	2.31	2.24
Illinois	697,565	862,321	1,280,807	285,719	375,949	475,541	2.44	2.29	2.69
Indiana	262,508	389,982	584,418	114,188	155,096	189,919	2.30	2.51	3.08
Iowa	259,437	332,402	439,810	57,698	76,976	90,942	4.50	4.32	4.84
Kansas	124,174	181,775	268,800	53,576	68,160	87,196	2.32	2.67	3.08
Kentucky	97,989	148,376	296,895	70,834	95,536	120,266	1.38	1.55	2.47
Louisiana	235,726	307,839	432,356	95,918	116,867	148,697	2.46	2.63	2.91
Maine	27,082	34,684	68,034	23,635	28,925	37,449	1.15	1.20	1.82
Maryland	626,903	801,338	1,162,523	117,630	145,061	195,007	5.33	5.52	5.96
Massachusetts	953,708	1,178,562	1,576,517	161,517	210,127	287,802	5.90	5.61	5.48
Michigan	601,189	807,900	1,107,195	194,230	265,130	320,470	3.10	3.05	3.45
Minnesota	331,471	341,468	469,208	103,923	141,540	188,050	3.19	2.41	2.50
Mississippi	100,383	124,675	242,133	41,311	56,575	67,125	2.43	2.20	3.61
Missouri	305,780	404,875	678,460	110,396	146,537	181,493	2.77	2.76	3.74
Montana	38,149	71,518	107,744	14,075	18,074	22,635	2.71	3.96	4.76
Nebraska	125,065	158,398	241,638	35,482	47,772	56,967	3.52	3.32	4.24
Nevada	66,742	84,970	115,934	33,665	54,564	79,220	1.98	1.56	1.46
New Hampshire	78,975	98,638	196,975	24,948	35,068	47,183	3.17	2.81	4.17
New Jersey	352,310	452,917	609,470	224,307	285,738	365,388	1.57	1.59	1.67
New Mexico	170,139	213,691	274,209	30,862	44,114	55,426	5.51	4.84	4.95
New York	1,427,840	1,732,340	2,476,090	504,665	633,830	826,488	2.83	2.73	3.00
North Carolina	501,841	741,679	1,137,279	147,473	204,329	275,615	3.40	3.63	4.13
North Dakota	48,930	71,849	84,574	11,634	15,855	19,005	4.21	4.53	4.45
Ohio	503,725	693,786	995,972	235,876	306,333	373,708	2.14	2.26	2.67
Oklahoma	152,624	201,626	255,217	59,698	74,855	93,855	2.56	2.69	2.72
Oregon	179,384	276,109	366,023	60,602	91,709	120,055	2.96	3.01	3.05
Pennsylvania	878,826	1,189,746	1,687,457	260,591	329,660	408,373	3.37	3.61	4.13
Rhode Island	88,448	107,266	142,564	21,758	26,656	36,939	4.07	4.02	3.86
South Carolina	151,204	217,881	361,404	68,776	89,854	115,204	2.20	2.42	3.14
South Dakota	15,959	25,440	32,185	14,093	19,372	24,251	1.13	1.31	1.33
Tennessee	243,763	317,090	423,264	102,049	142,051	182,515	2.39	2.23	2.32
Texas	1,220,313	1,527,990	2,244,117	403,286	553,180	763,874	3.03	2.76	2.94
Utah	201,470	207,923	338,127	33,658	51,523	70,409	5.99	4.04	4.80
Vermont	46,541	53,659	76,882	11,771	14,662	19,149	3.95	3.66	4.01
Virginia	343,464	411,825	610,717	153,965	199,953	273,070	2.23	2.06	2.24
Washington	349,667	505,113	706,579	122,453	161,779	222,950	2.86	3.12	3.17
West Virginia	50,772	55,206	79,076	29,331	37,220	42,368	1.73	1.48	1.87
Wisconsin	387,621	485,560	728,618	104,918	141,046	177,354	3.69	3.44	4.11
Wyoming	23,009	40,553	41,632	13,550	15,879	20,418	1.70	2.55	2.04
Puerto Rico	NA	NA	63,755	22,809	30,357	NA	NA	NA	NA

GSP gross state product
NA not available

NOTES: The state total for academic R&D for each year is the sum of the 50 states and the District of Columbia. In 2001, academic R&D was reported for all institutions. In 1991 and 1996, it was reported for doctorate-granting institutions only. For Maryland, academic R&D excludes R&D performed by the Applied Physics Laboratory at the Johns Hopkins University. GSP is reported in current dollars.

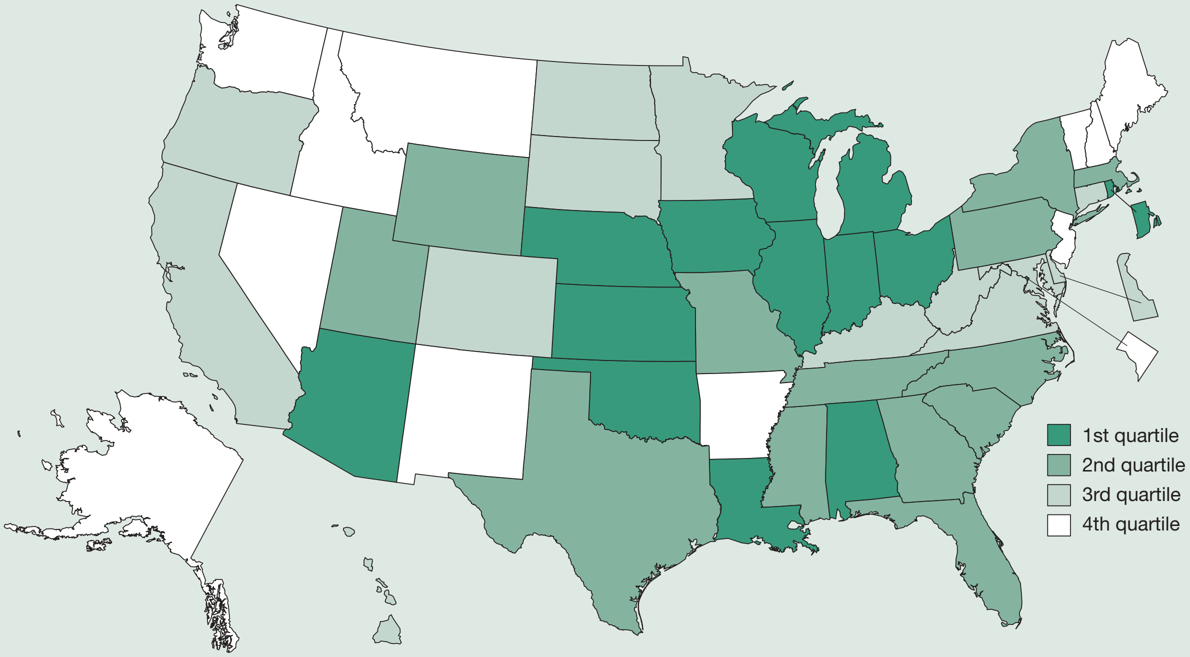
SOURCES: National Science Foundation, Division of Science Resources Statistics, *Academic Research and Development Expenditures,* various years; U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data; and Government of Puerto Rico, Office of the Governor.

Science & Engineering Indicators – 2004

S&E Doctorates Conferred per 1,000 S&E Doctorate Holders

Figure 8-17

Quartile groups for S&E doctorates conferred per 1,000 S&E doctorate holders: 2001



1st quartile (92.3–55.2)	2nd quartile (53.9–44.8)	3rd quartile (44.5–34.0)	4th quartile (33.7–15.6)
Alabama	Florida	California	Alaska
Arizona	Georgia	Colorado	Arkansas
Illinois	Massachusetts	Connecticut	District of Columbia
Indiana	Mississippi	Delaware	Idaho
Iowa	Missouri	Hawaii	Maine
Kansas	New York	Kentucky	Montana
Louisiana	North Carolina	Maryland	Nevada
Michigan	Pennsylvania	Minnesota	New Hampshire
Nebraska	South Carolina	North Dakota	New Jersey
Ohio	Tennessee	Oregon	New Mexico
Oklahoma	Texas	South Dakota	Vermont
Rhode Island	Utah	Virginia	Washington
Wisconsin	Wyoming	West Virginia	

SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), Survey of Earned Doctorates; and NSF/SRS, Survey of Doctorate Recipients. See table 8-17.

This indicator is a measure of the rate at which the states are training new science and engineering doctorate recipients for entry into the workforce. High values indicate relatively large production of new doctorate holders compared with the existing stock. Some states with relatively low values may need to attract S&E doctorate holders from elsewhere to meet the needs of local employers.

U.S. S&E doctorate holders include those in physical, earth, atmospheric, ocean, life, computer, and social sciences; mathematics; engineering; and psychology. Medical doctorates are excluded.

Findings

- In 2001, 27,000 S&E doctoral degrees were awarded by U.S. academic institutions, which was essentially the same as in 1993.
- The state average of this indicator decreased between 1993 and 2001, reflecting an increase in the stock of S&E doctorate holders in the United States.
- This indicator is volatile for many states, which may reflect the migration patterns of existing S&E doctorate holders.

Table 8-17
S&E doctorates conferred per 1,000 S&E doctorate holders, by state: 1993, 1997 and 2001

	S&E doctorates conferred			U.S. S&E doctorate holders			S&E doctorates conferred per 1,000 U.S. S&E doctorate holders		
State	1993	1997	2001	1993	1997	2001	1993	1997	2001
All states	26,614	28,579	27,025	461,210	516,580	572,820	57.7	55.3	47.2
Alabama	276	369	320	5,020	6,610	5,330	55.0	55.8	60.0
Alaska	10	20	26	1,050	1,110	1,200	9.5	18.0	21.7
Arizona	428	497	419	5,040	6,280	7,070	84.9	79.1	59.3
Arkansas	61	70	69	1,770	2,320	2,560	34.5	30.2	27.0
California	3,600	3,604	3,550	60,490	70,490	80,870	59.5	51.1	43.9
Colorado	527	597	519	8,890	10,740	11,780	59.3	55.6	44.1
Connecticut	411	409	387	7,510	8,770	9,490	54.7	46.6	40.8
Delaware	123	131	128	3,500	3,710	3,540	35.1	35.3	36.2
District of Columbia	342	331	302	13,510	11,800	14,200	25.3	28.1	21.3
Florida	642	862	848	11,770	13,330	15,740	54.5	64.7	53.9
Georgia	488	583	644	8,130	9,880	11,990	60.0	59.0	53.7
Hawaii	133	134	111	2,360	2,550	2,580	56.4	52.5	43.0
Idaho	48	60	54	1,860	2,030	2,230	25.8	29.6	24.2
Illinois	1,451	1,447	1,388	19,160	21,260	22,110	75.7	68.1	62.8
Indiana	722	727	699	7,610	7,570	9,580	94.9	96.0	73.0
Iowa	457	437	405	3,790	4,120	4,390	120.6	106.1	92.3
Kansas	246	297	286	3,290	3,770	3,970	74.8	78.8	72.0
Kentucky	173	225	183	3,570	4,110	4,590	48.5	54.7	39.9
Louisiana	270	362	368	5,230	5,360	5,290	51.6	67.5	69.6
Maine	30	41	31	1,830	2,150	1,990	16.4	19.1	15.6
Maryland	715	786	774	18,390	21,020	22,730	38.9	37.4	34.1
Massachusetts	1,545	1,575	1,547	21,360	23,330	29,100	72.3	67.5	53.2
Michigan	990	1,035	960	13,020	15,060	17,380	76.0	68.7	55.2
Minnesota	487	531	508	8,030	9,810	11,410	60.6	54.1	44.5
Mississippi	128	158	142	2,750	3,000	3,170	46.5	52.7	44.8
Missouri	389	497	465	7,970	9,490	9,280	48.8	52.4	50.1
Montana	46	59	42	1,460	1,690	1,440	31.5	34.9	29.2
Nebraska	135	193	171	2,380	3,010	2,890	56.7	64.1	59.2
Nevada	24	49	54	1,380	1,620	2,030	17.4	30.2	26.6
New Hampshire	99	95	79	1,990	2,230	2,470	49.7	42.6	32.0
New Jersey	555	630	636	19,320	20,440	22,740	28.7	30.8	28.0
New Mexico	178	165	153	6,320	7,480	7,750	28.2	22.1	19.7
New York	2,604	2,434	2,224	39,110	40,080	43,990	66.6	60.7	50.6
North Carolina	706	777	771	12,220	13,730	16,760	57.8	56.6	46.0
North Dakota	54	52	43	1,200	1,350	1,080	45.0	38.5	39.8
Ohio	1,043	1,295	1,139	16,700	18,700	20,070	62.5	69.3	56.8
Oklahoma	220	244	241	4,410	4,580	4,360	49.9	53.3	55.3
Oregon	322	317	274	5,600	6,210	7,040	57.5	51.0	38.9
Pennsylvania	1,365	1,448	1,354	21,990	23,940	26,140	62.1	60.5	51.8
Rhode Island	217	165	168	2,060	2,450	2,640	105.3	67.3	63.6
South Carolina	240	251	249	4,310	4,780	5,130	55.7	52.5	48.5
South Dakota	20	37	34	930	1,060	1,000	21.5	34.9	34.0
Tennessee	350	423	404	7,660	8,520	8,990	45.7	49.6	44.9
Texas	1,599	1,749	1,720	25,880	28,570	32,490	61.8	61.2	52.9
Utah	283	296	259	3,720	4,800	4,820	76.1	61.7	53.7
Vermont	47	35	52	1,500	1,760	1,750	31.3	19.9	29.7
Virginia	681	710	667	13,710	15,250	17,460	49.7	46.6	38.2
Washington	444	514	497	10,570	13,360	14,760	42.0	38.5	33.7
West Virginia	67	82	68	1,760	1,980	1,890	38.1	41.4	36.0
Wisconsin	585	708	555	7,410	8,460	8,720	78.9	83.7	63.6
Wyoming	38	66	38	720	860	840	52.8	76.7	45.2
Puerto Rico	26	84	97	NA	NA	NA	NA	NA	NA

NA not available

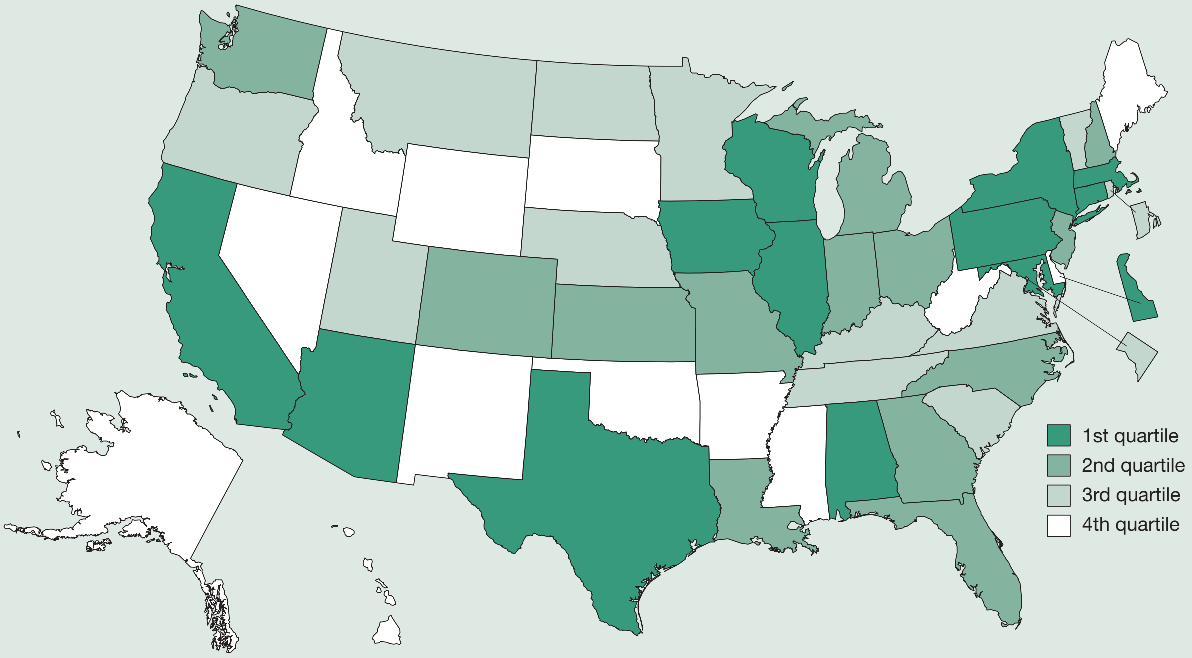
NOTES: The state total for each year is the sum of the 50 states and the District of Columbia. The Survey of Doctorate Recipients sample design does not include geography. Data on U.S. S&E doctorate holders are classified by employment location and workforce data based on respondents' residence. Thus, the reliability of data for areas with smaller populations is lower than for more populous states. The reliability of estimates for the 1993 U.S. S&E doctorate holders for Alaska, North Dakota, South Dakota, and Wyoming may be poor because of small sample size. The reliability of estimates for the 1997 U.S. S&E doctorate holders for Alaska, Montana, Nevada, North Dakota, South Dakota, Vermont, West Virginia, and Wyoming may be poor because of small sample size. The reliability of estimates for the 2001 holders of a U.S. S&E doctorate for Alaska, Montana, North Dakota, South Dakota, Vermont, West Virginia, and Wyoming may be poor because of small sample size.

SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), Survey of Earned Doctorates; and NSF/SRS, Survey of Doctorate Recipients.

Science & Engineering Indicators – 2004

Academic Article Output per 1,000 S&E Doctorate Holders in Academia

Figure 8-18
Quartile groups for article output per 1,000 S&E doctorate holders in academia: 2001



1st quartile (889–632)	2nd quartile (604–540)	3rd quartile (525–406)	4th quartile (385–195)
Alabama	Colorado	District of Columbia	Alaska
Arizona	Florida	Kentucky	Arkansas
California	Georgia	Minnesota	Hawaii
Connecticut	Indiana	Montana	Idaho
Delaware	Kansas	Nebraska	Maine
Illinois	Louisiana	North Dakota	Mississippi
Iowa	Michigan	Oregon	Nevada
Maryland	Missouri	Rhode Island	New Mexico
Massachusetts	New Hampshire	South Carolina	Oklahoma
New York	New Jersey	Tennessee	South Dakota
Pennsylvania	North Carolina	Utah	West Virginia
Texas	Ohio	Vermont	Wyoming
Wisconsin	Washington	Virginia	

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients. See table 8-18.

The volume of peer-reviewed articles per 1,000 academic science and engineering doctorate holders is an approximate measure of their contribution to scientific knowledge. Publications are only one measure of academic productivity, which includes trained personnel, patents, and other outputs. A high value on this indicator shows that the S&E faculty in a state's academic institutions are generating a high volume of publications relative to other states.

Publication counts are based on the number of articles appearing in a set of journals listed in the Institute for Scientific Information's Science Citation Index and Social Sciences Citation Index. The number of journals was 4,601 in 1993, 5,029 in 1997, and 5,262 in 2001. Articles with authors in different institutions were counted fractionally. For a publication with N authors, each author's institution was credited with 1/N articles.

Findings

- The state average of this indicator declined between 1993 and 2001.
- During this period, the number of scientific and technical articles remained fairly constant at 140,000–150,000, whereas the number of S&E doctorate holders employed in academia rose from 210,000 to 245,000.
- The indicator values of many states were volatile between 1993 and 2001.
- In 2001, the states with the highest values for this indicator were spread across the nation.

Table 8-18
Academic article output per 1,000 S&E doctorate holders in academia, by state: 1993, 1997, and 2001

State	Academic article output			S&E doctorate holders in academia			Academic article output per 1,000 S&E doctorate holders in academia		
	1993	1997	2001	1993	1997	2001	1993	1997	2001
All states	142,023	144,404	147,561	209,070	232,100	243,890	679	622	605
Alabama	1,787	1,911	1,896	3,010	4,480	3,000	594	426	632
Alaska	169	163	186	530	430	530	318	380	351
Arizona	2,249	2,256	2,199	2,540	2,740	2,950	885	823	746
Arkansas	562	603	608	1,210	1,490	1,580	464	405	385
California	18,010	17,530	18,148	21,330	23,970	24,090	844	731	753
Colorado	2,355	2,523	2,630	3,580	4,400	4,830	658	573	544
Connecticut	2,723	2,820	2,767	3,540	3,830	4,120	769	736	672
Delaware	530	499	560	650	710	760	815	703	737
District of Columbia	1,187	1,224	1,213	2,010	2,180	2,720	590	562	446
Florida	4,146	4,187	4,256	5,720	6,110	7,230	725	685	589
Georgia	2,880	3,255	3,578	4,050	5,260	5,970	711	619	599
Hawaii	585	574	538	1,340	1,240	1,440	437	463	374
Idaho	297	295	309	810	750	890	367	393	347
Illinois	7,100	6,894	7,012	9,650	10,080	10,320	736	684	679
Indiana	3,077	3,104	3,096	4,460	4,560	5,620	690	681	551
Iowa	2,292	2,272	2,226	2,940	3,090	3,220	779	735	691
Kansas	1,244	1,199	1,251	2,050	2,230	2,180	607	538	574
Kentucky	1,310	1,381	1,355	2,500	2,920	3,190	524	473	425
Louisiana	1,787	1,895	1,828	3,230	3,420	3,290	553	554	556
Maine	245	247	234	1,190	1,310	1,200	206	189	195
Maryland	4,237	4,319	4,851	4,520	5,820	5,460	937	742	889
Massachusetts	8,630	9,238	9,680	10,930	11,500	12,880	790	803	752
Michigan	4,892	4,880	5,078	7,000	7,690	8,520	699	635	596
Minnesota	2,493	2,435	2,389	3,890	4,300	5,140	641	566	465
Mississippi	507	628	692	1,840	1,890	1,890	275	332	366
Missouri	2,946	3,163	3,230	4,360	5,480	5,360	676	577	603
Montana	265	272	328	880	1,020	810	301	267	406
Nebraska	1,067	1,030	1,011	1,770	2,310	1,940	603	446	521
Nevada	375	370	447	770	960	1,180	487	386	379
New Hampshire	613	651	678	1,030	1,050	1,180	595	620	574
New Jersey	2,820	3,094	3,049	4,240	4,760	5,360	665	650	569
New Mexico	734	808	780	3,060	2,300	2,720	240	351	287
New York	12,783	12,384	12,434	18,020	19,050	19,640	709	650	633
North Carolina	4,678	4,958	5,140	6,940	7,500	8,510	674	661	604
North Dakota	281	269	271	820	900	660	342	299	410
Ohio	5,212	5,169	5,080	8,220	9,320	9,400	634	555	540
Oklahoma	892	919	925	2,470	2,570	2,600	361	357	356
Oregon	1,574	1,613	1,539	2,480	2,510	2,990	635	643	515
Pennsylvania	7,784	8,194	8,362	10,810	11,830	13,040	720	693	641
Rhode Island	872	852	862	1,420	1,650	1,640	614	517	525
South Carolina	1,137	1,201	1,343	2,470	3,010	2,750	460	399	488
South Dakota	140	140	131	650	670	610	215	208	215
Tennessee	2,084	2,255	2,286	4,080	4,610	4,580	511	489	499
Texas	8,671	8,755	9,038	11,130	12,980	13,140	779	675	688
Utah	1,508	1,569	1,570	2,230	2,950	2,990	676	532	525
Vermont	393	380	412	910	1,100	950	431	345	434
Virginia	3,043	3,013	3,104	5,320	5,340	6,390	572	564	486
Washington	2,989	3,206	3,339	4,320	5,050	5,930	692	635	563
West Virginia	395	417	388	990	1,160	1,130	399	360	344
Wisconsin	3,258	3,189	3,044	4,680	5,080	4,820	696	628	632
Wyoming	218	200	190	480	540	550	455	371	345
Puerto Rico	168	168	186	NA	NA	NA	NA	NA	NA

NA not available

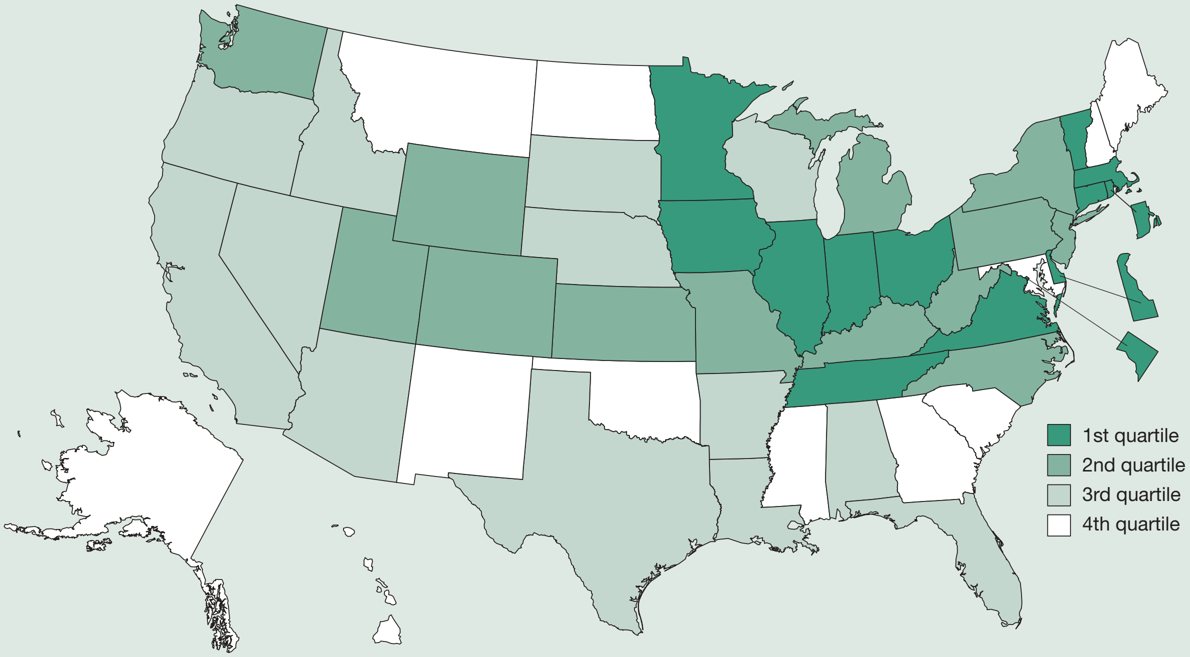
NOTES: The state total for each year is the sum of the 50 states and the District of Columbia. The Survey of Doctorate Recipients sample design does not include geography. The reliability of estimates for the 1993 S&E doctorate holders in academia for Alaska, Arkansas, Delaware, Hawaii, Idaho, Maine, Montana, Nevada, New Hampshire, North Dakota, South Dakota, Vermont, West Virginia, and Wyoming may be poor because of small sample size. The reliability of estimates for the 1997 S&E doctorate holders in academia for Alaska, Arkansas, Delaware, Hawaii, Idaho, Maine, Mississippi, Montana, Nevada, New Hampshire, North Dakota, Rhode Island, South Dakota, Vermont, West Virginia, and Wyoming may be poor because of small sample size. The reliability of estimates for the 2001 S&E doctorate holders in academia for Alaska, Arkansas, Delaware, Hawaii, Idaho, Maine, Mississippi, Montana, Nevada, New Hampshire, North Dakota, Rhode Island, South Dakota, Vermont, West Virginia, and Wyoming may be poor because of small sample size.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients.

Science & Engineering Indicators – 2004

Academic Article Output per $1 Million of Academic R&D

Figure 8-19
Quartile groups for academic article output per $1 million of academic R&D: 2001



1st quartile (7.00–5.06)	2nd quartile (5.02–4.52)	3rd quartile (4.39–3.74)	4th quartile (3.72–1.61)
Connecticut	Colorado	Alabama	Alaska
Delaware	Kansas	Arizona	Georgia
District of Columbia	Kentucky	Arkansas	Hawaii
Illinois	Michigan	California	Maine
Indiana	Missouri	Florida	Maryland
Iowa	New Jersey	Idaho	Mississippi
Massachusetts	New York	Louisiana	Montana
Minnesota	North Carolina	Nebraska	New Hampshire
Ohio	Pennsylvania	Nevada	New Mexico
Rhode Island	Utah	Oregon	North Dakota
Tennessee	Washington	South Dakota	Oklahoma
Vermont	West Virginia	Texas	South Carolina
Virginia	Wyoming	Wisconsin	

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, *Academic Research and Development Expenditures.* See table 8-19.

This indicator shows the relationship between the number of academic publications and the expenditure for academic research and development. A high value for this indicator means that a state's academic institutions have a high publications output relative to their R&D spending. This indicator is not an efficiency measure; it is affected by the highly variable costs of R&D and by publishing conventions in different fields and institutions and thus reflects variations in field emphasis among states and institutions.

Publication counts are based on the number of articles appearing in a set of journals listed in the Institute for Scientific Information's Science Citation Index and Social Sciences Citation Index. The number of journals was 4,601 in 1993, 5,029 in 1997, and 5,262 in 2001. Articles with authors in different institutions were counted fractionally. For a publication with N authors, each author's institution was credited with 1/N articles. In this indicator, Maryland data exclude expenditures by the Applied Physics Laboratory at the Johns Hopkins University.

Findings

- From 1993 to 2001, the number of academic publications remained fairly constant at 140,000–150,000 annually.
- In 2001, academic researchers produced an average of 4.5 publications per $1 million academic R&D, compared with 7.3 in 1993. This partly reflects the effects of general price inflation but may also indicate rising academic research costs.
- The value of this indicator decreased for all states between 1993 and 2001.

Table 8-19

Academic article output per $1 million of academic R&D, by state: 1993, 1997, and 2001

	Academic article output			Academic R&D (millions of dollars)			Academic article output per $1 million academic R&D		
State	1993	1997	2001	1993	1997	2001	1993	1997	2001
All states	142,023	144,404	147,561	19,568	23,852	32,652	7.26	6.05	4.52
Alabama	1,787	1,911	1,896	281	369	445	6.35	5.18	4.26
Alaska	169	163	186	67	71	116	2.52	2.30	1.61
Arizona	2,249	2,256	2,199	311	377	501	7.24	5.99	4.39
Arkansas	562	603	608	75	103	141	7.51	5.85	4.32
California	18,010	17,530	18,148	2,381	3,049	4,422	7.56	5.75	4.10
Colorado	2,355	2,523	2,630	331	427	573	7.11	5.90	4.59
Connecticut	2,723	2,820	2,767	365	393	499	7.47	7.18	5.55
Delaware	530	499	560	53	65	80	10.07	7.66	7.00
District of Columbia	1,187	1,224	1,213	145	214	228	8.17	5.72	5.32
Florida	4,146	4,187	4,256	489	702	997	8.49	5.96	4.27
Georgia	2,880	3,255	3,578	547	766	989	5.27	4.25	3.62
Hawaii	585	574	538	74	120	157	7.91	4.78	3.43
Idaho	297	295	309	49	63	82	6.10	4.68	3.74
Illinois	7,100	6,894	7,012	758	927	1,281	9.37	7.44	5.47
Indiana	3,077	3,104	3,096	303	400	584	10.16	7.75	5.30
Iowa	2,292	2,272	2,226	299	342	440	7.67	6.65	5.06
Kansas	1,244	1,199	1,251	154	198	269	8.07	6.07	4.65
Kentucky	1,310	1,381	1,355	122	158	297	10.70	8.72	4.56
Louisiana	1,787	1,895	1,828	255	332	432	7.00	5.70	4.23
Maine	245	247	234	25	33	68	9.85	7.45	3.44
Maryland	4,237	4,319	4,851	1,148	1,272	1,644	3.69	3.40	2.95
Massachusetts	8,630	9,238	9,680	1,108	1,273	1,577	7.79	7.26	6.14
Michigan	4,892	4,880	5,078	700	842	1,107	6.99	5.79	4.59
Minnesota	2,493	2,435	2,389	332	363	469	7.50	6.70	5.09
Mississippi	507	628	692	106	125	242	4.79	5.04	2.86
Missouri	2,946	3,163	3,230	345	459	678	8.55	6.89	4.76
Montana	265	272	328	48	71	108	5.51	3.86	3.05
Nebraska	1,067	1,030	1,011	137	177	242	7.78	5.81	4.18
Nevada	375	370	447	79	88	116	4.74	4.19	3.86
New Hampshire	613	651	678	99	108	197	6.17	6.06	3.44
New Jersey	2,820	3,094	3,049	374	462	609	7.54	6.70	5.00
New Mexico	734	808	780	187	219	274	3.93	3.69	2.84
New York	12,783	12,384	12,434	1,554	1,780	2,476	8.23	6.96	5.02
North Carolina	4,678	4,958	5,140	617	802	1,137	7.59	6.18	4.52
North Dakota	281	269	271	54	56	85	5.18	4.80	3.20
Ohio	5,212	5,169	5,080	593	764	996	8.79	6.77	5.10
Oklahoma	892	919	925	173	187	255	5.15	4.92	3.63
Oregon	1,574	1,613	1,539	226	291	366	6.97	5.55	4.20
Pennsylvania	7,784	8,194	8,362	1,019	1,241	1,687	7.64	6.60	4.96
Rhode Island	872	852	862	103	112	143	8.45	7.61	6.04
South Carolina	1,137	1,201	1,343	178	219	361	6.38	5.48	3.72
South Dakota	140	140	131	22	25	32	6.31	5.68	4.08
Tennessee	2,084	2,255	2,286	278	330	423	7.50	6.84	5.40
Texas	8,671	8,755	9,038	1,398	1,607	2,244	6.20	5.45	4.03
Utah	1,508	1,569	1,570	195	239	338	7.74	6.57	4.64
Vermont	393	380	412	50	60	77	7.88	6.38	5.36
Virginia	3,043	3,013	3,104	404	456	611	7.53	6.61	5.08
Washington	2,989	3,206	3,339	428	508	707	6.99	6.31	4.73
West Virginia	395	417	388	55	64	79	7.19	6.56	4.91
Wisconsin	3,258	3,189	3,044	444	497	729	7.33	6.41	4.18
Wyoming	218	200	190	33	48	42	6.70	4.20	4.56
Puerto Rico	168	168	186	NA	NA	64	NA	NA	2.92

NA not available

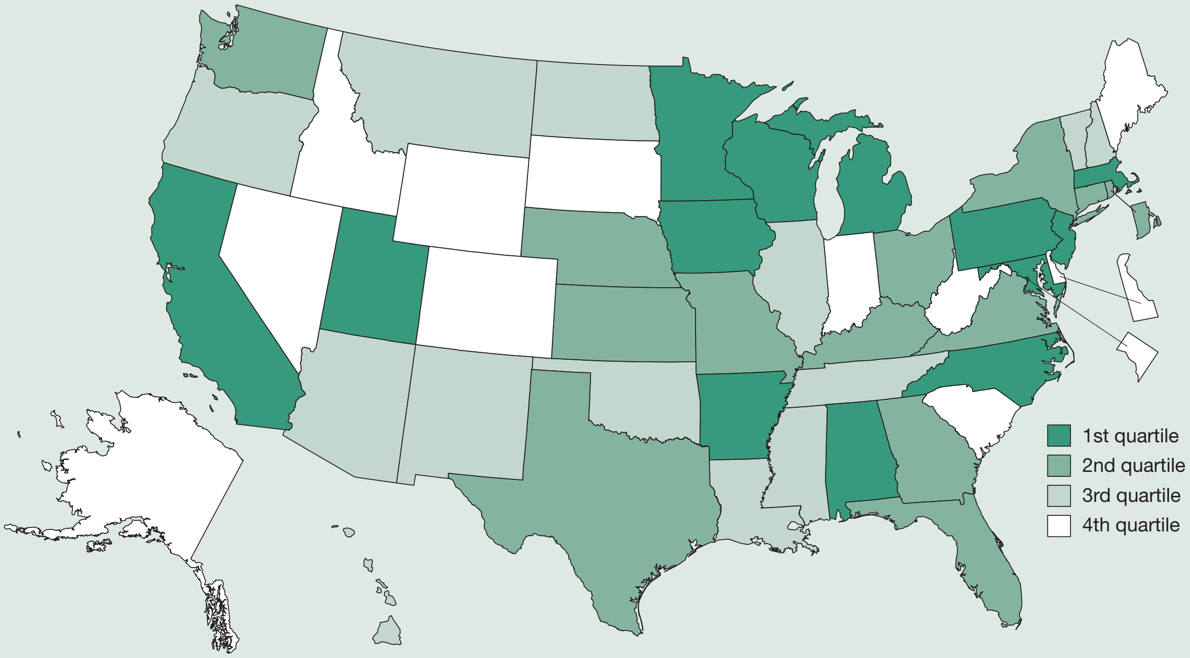
NOTES: The state total for each year is the sum of the 50 states and the District of Columbia. In 2001, academic R&D was reported for all institutions. In 1993 and 1997, academic R&D was reported for doctorate-granting institutions only.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, *Academic Research and Development Expenditures,* various years.

Science & Engineering Indicators – 2004

Academic Patents Awarded per 1,000 S&E Doctorate Holders in Academia

Figure 8-20
Quartile groups for academic patents awarded per 1,000 S&E doctorate holders in academia: 1999



1st quartile (26.7–15.0)	2nd quartile (14.9–9.5)	3rd quartile (9.5–5.3)	4th quartile (5.1–0.0)
Alabama	Connecticut	Arizona	Alaska
Arkansas	Florida	Hawaii	Colorado
California	Georgia	Illinois	Delaware
Iowa	Kansas	Louisiana	District of Columbia
Maryland	Kentucky	Mississippi	Idaho
Massachusetts	Missouri	Montana	Indiana
Michigan	Nebraska	New Hampshire	Maine
Minnesota	New York	New Mexico	Nevada
New Jersey	Ohio	North Dakota	South Carolina
North Carolina	Rhode Island	Oklahoma	South Dakota
Pennsylvania	Texas	Oregon	West Virginia
Utah	Virginia	Tennessee	Wyoming
Wisconsin	Washington	Vermont	

SOURCES: U.S. Patent and Trademark Office, Technology Assessment and Forecast Branch, *U.S. Colleges and Universities–Utility Patent Grants, Calendar Years 1969–2000;* and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients. See table 8-20.

Since the early 1980s, academic institutions have increasingly been viewed as engines of economic growth. Growing attention has been paid to the results of academic research and development in terms of its role in developing new products, processes, and services. One indicator of such R&D results is the volume of academic patents. Academic patenting is highly concentrated and partly reflects the resources devoted to institutional patenting offices.

This indicator relates the volume of academic patents to the size of the doctoral S&E workforce in academia. It is an approximate measure of the degree to which results with perceived economic value are generated by the doctoral academic workforce.

S&E doctorates include physical, life, computer, earth, atmospheric, ocean, and social sciences; mathematics; engineering; and psychology. Medical doctorates and S&E doctorates from foreign institutions are excluded.

Findings

- The number of patents awarded to academic institutions more than doubled between 1993 and 1999, from about 1,600 to 3,300, whereas the number of academic S&E doctorate holders rose by 14 percent.
- In 1999, 14 patents were produced for each 1,000 S&E doctorate holders employed in academia, which was almost double the number in 1993.
- The rise in this indicator suggests that states and their universities may be focusing on academic patenting more than in the past.
- States vary widely on this indicator, which ranges from 0 to 27 patents per 1,000 S&E doctorate holders employed in academia.

Table 8-20
Academic patents awarded per 1,000 S&E doctorate holders in academia, by state: 1993, 1997, and 1999

	Patents awarded to academic institutions			S&E doctorate holders in academia			Patents per 1,000 S&E doctorate holders in academia		
State	1993	1997	1999	1993	1997	1999	1993	1997	1999
All states	1,619	2,436	3,340	209,070	232,100	238,990	7.7	10.5	14.0
Alabama	11	23	48	3,010	4,480	3,200	3.7	5.1	15.0
Alaska*	1	2	0	530	430	540	1.9	4.7	0.0
Arizona	6	21	18	2,540	2,740	2,790	2.4	7.7	6.5
Arkansas*	8	8	31	1,210	1,490	1,660	6.6	5.4	18.7
California	211	409	641	21,330	23,970	23,990	9.9	17.1	26.7
Colorado	20	30	19	3,580	4,400	4,620	5.6	6.8	4.1
Connecticut	25	34	45	3,540	3,830	4,460	7.1	8.9	10.1
Delaware*	5	4	2	650	710	670	7.7	5.6	3.0
District of Columbia	18	28	14	2,010	2,180	2,760	9.0	12.8	5.1
Florida	60	94	95	5,720	6,110	7,030	10.5	15.4	13.5
Georgia	49	42	70	4,050	5,260	5,480	12.1	8.0	12.8
Hawaii*	8	6	8	1,340	1,240	1,360	6.0	4.8	5.9
Idaho*	0	0	0	810	750	760	0.0	0.0	0.0
Illinois	38	78	95	9,650	10,080	10,020	3.9	7.7	9.5
Indiana	10	38	24	4,460	4,560	5,160	2.2	8.3	4.7
Iowa	41	51	78	2,940	3,090	3,290	13.9	16.5	23.7
Kansas*	12	7	23	2,050	2,230	1,860	5.9	3.1	12.4
Kentucky	5	16	32	2,500	2,920	3,070	2.0	5.5	10.4
Louisiana	22	26	17	3,230	3,420	3,210	6.8	7.6	5.3
Maine*	0	0	1	1,190	1,310	1,280	0.0	0.0	0.8
Maryland	54	66	134	4,520	5,820	5,490	11.9	11.3	24.4
Massachusetts	171	188	271	10,930	11,500	13,120	15.6	16.3	20.7
Michigan	48	104	120	7,000	7,690	7,740	6.9	13.5	15.5
Minnesota	37	50	77	3,890	4,300	5,000	9.5	11.6	15.4
Mississippi*	5	6	14	1,840	1,890	2,030	2.7	3.2	6.9
Missouri	26	40	78	4,360	5,480	5,230	6.0	7.3	14.9
Montana*	1	4	8	880	1,020	1,030	1.1	3.9	7.8
Nebraska*	10	27	23	1,770	2,310	1,810	5.6	11.7	12.7
Nevada*	0	2	3	770	960	920	0.0	2.1	3.3
New Hampshire*	4	3	8	1,030	1,050	1,020	3.9	2.9	7.8
New Jersey	27	52	85	4,240	4,760	4,610	6.4	10.9	18.4
New Mexico	7	18	21	3,060	2,300	2,620	2.3	7.8	8.0
New York	163	224	291	18,020	19,050	19,890	9.0	11.8	14.6
North Carolina	65	96	124	6,940	7,500	8,020	9.4	12.8	15.5
North Dakota*	5	5	6	820	900	780	6.1	5.6	7.7
Ohio	58	75	94	8,220	9,320	9,860	7.1	8.0	9.5
Oklahoma	14	17	21	2,470	2,570	2,410	5.7	6.6	8.7
Oregon	12	27	22	2,480	2,510	2,940	4.8	10.8	7.5
Pennsylvania	86	138	211	10,810	11,830	12,800	8.0	11.7	16.5
Rhode Island*	1	9	19	1,420	1,650	1,710	0.7	5.5	11.1
South Carolina	6	14	11	2,470	3,010	2,700	2.4	4.7	4.1
South Dakota*	0	2	1	650	670	660	0.0	3.0	1.5
Tennessee	11	25	27	4,080	4,610	4,310	2.7	5.4	6.3
Texas	124	125	147	11,130	12,980	12,880	11.1	9.6	11.4
Utah	35	37	42	2,230	2,950	2,740	15.7	12.5	15.3
Vermont*	1	3	6	910	1,100	990	1.1	2.7	6.1
Virginia	28	49	67	5,320	5,340	6,290	5.3	9.2	10.7
Washington	13	42	57	4,320	5,050	5,430	3.0	8.3	10.5
West Virginia*	0	2	1	990	1,160	1,140	0.0	1.7	0.9
Wisconsin	57	65	87	4,680	5,080	5,020	12.2	12.8	17.3
Wyoming*	0	4	3	480	540	590	0.0	7.4	5.1
Puerto Rico	1	0	0	NA	NA	NA	NA	NA	NA

NA not available

*Reliability of estimates for some states may be poor because of small sample size.

NOTES: The state total for each year is the sum of the 50 states and the District of Columbia. The Survey of Doctorate Recipients sample design does not include geography.

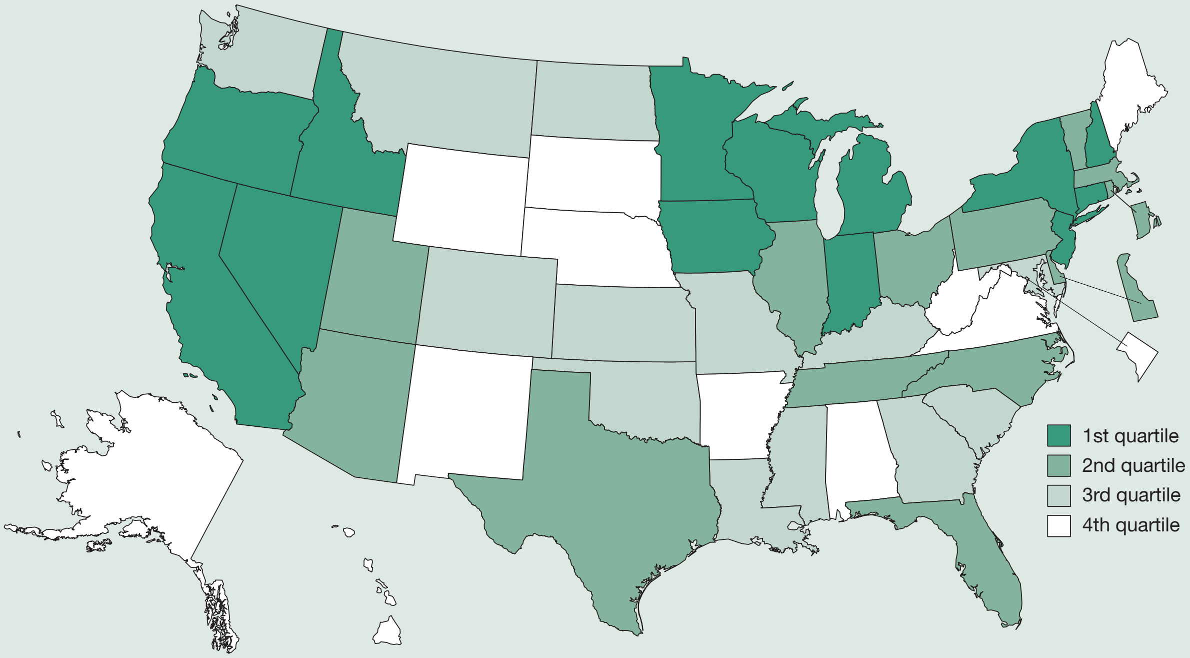
SOURCES: U.S. Patent and Trademark Office, Technology Assessment and Forecast Branch, *U.S. Colleges and Universities–Utility Patent Grants, Calendar Years 1969–2000;* and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients.

Science & Engineering Indicators – 2004

Patents Awarded per 1,000 Individuals in S&E Occupations

Figure 8-21

Quartile groups for patents awarded per 1,000 individuals in S&E occupations: 1999



1st quartile (81.5–30.5)	2nd quartile (30.1–20.9)	3rd quartile (20.5–14.0)	4th quartile (13.4–1.2)
California	Arizona	Colorado	Alabama
Connecticut	Delaware	Georgia	Alaska
Idaho	Florida	Kansas	Arkansas
Indiana	Illinois	Kentucky	District of Columbia
Iowa	Massachusetts	Louisiana	Hawaii
Michigan	North Carolina	Maryland	Maine
Minnesota	Ohio	Mississippi	Nebraska
Nevada	Pennsylvania	Missouri	New Mexico
New Hampshire	Rhode Island	Montana	South Dakota
New Jersey	Tennessee	North Dakota	Virginia
New York	Texas	Oklahoma	West Virginia
Oregon	Utah	South Carolina	Wyoming
Wisconsin	Vermont	Washington	

SOURCES: U.S. Patent and Trademark Office, Information Products Division/Technology Assessment and Forecast Branch, *Patent Counts by Country/State and Year, All Patents, All Types, January 1, 1977–December 31, 2001;* and National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT). See table 8-21.

This indicator shows state patent activity normalized to the size of its science and engineering workforce, specifically employees in S&E occupations. People in S&E occupations include computer, mathematical, life, physical, and social scientists; engineers; and postsecondary teachers in any of these fields. Managers, elementary and secondary school teachers, and medical personnel are excluded.

The U.S. Patent and Trademark Office classifies patents based on the residence of the first-named inventor. Only U.S.-origin patents are included.

Because of the different methods of assigning geographic location to the two indicator measures, this indicator is of limited applicability for sparsely populated states or for locations where a large percentage of the population lives in one state or region and works in another.

Findings

- The number of patents issued rose sharply between 1995 and 1999, from 64,500 to 94,000.
- In 1999, the state average for this indicator was 26.7 patents per 1,000 individuals in an S&E occupation, compared with 20.3 in 1995.
- The District of Columbia and Idaho were outliers, at 1.2 and 81.5, respectively, the latter reflecting the presence of a high-patenting Department of Energy National Laboratory in this sparsely populated state.
- The remaining states' values ranged widely on this indicator, from 8.3 to 38.3 patents per 1,000 individuals.

Table 8-21
Patents awarded per 1,000 individuals in S&E occupations, by state: 1995, 1997, and 1999

	Patents awarded			Individuals in S&E occupations			Patents per 1,000 individuals in S&E occupations		
State	1995	1997	1999	1995	1997	1999	1995	1997	1999
All states	64,480	69,898	94,046	3,178,000	3,357,000	3,525,100	20.3	20.8	26.7
Alabama	359	345	473	40,800	44,300	43,300	8.8	7.8	10.9
Alaska	49	60	66	6,600	6,300	7,700	7.4	9.5	8.6
Arizona	1,120	1,162	1,623	47,400	54,000	55,700	23.6	21.5	29.1
Arkansas	143	152	226	14,100	15,300	16,900	10.1	9.9	13.4
California	10,824	12,915	18,860	463,900	478,000	492,000	23.3	27.0	38.3
Colorado	1,207	1,345	1,987	82,700	88,500	96,900	14.6	15.2	20.5
Connecticut	1,768	1,644	2,026	56,900	53,300	57,500	31.1	30.8	35.2
Delaware	442	370	444	14,300	15,700	16,300	30.9	23.6	27.2
District of Columbia	63	59	63	53,200	51,300	53,900	1.2	1.2	1.2
Florida	2,465	2,552	3,040	105,500	116,600	123,000	23.4	21.9	24.7
Georgia	1,047	1,112	1,544	69,800	75,600	85,900	15.0	14.7	18.0
Hawaii	84	93	97	13,100	11,500	11,700	6.4	8.1	8.3
Idaho	329	597	1,263	13,200	13,900	15,500	24.9	42.9	81.5
Illinois	3,479	3,539	4,308	138,300	148,600	155,200	25.2	23.8	27.8
Indiana	1,281	1,331	1,707	51,300	54,000	56,000	25.0	24.6	30.5
Iowa	486	450	817	22,100	24,500	23,900	22.0	18.4	34.2
Kansas	319	322	495	29,500	34,300	31,400	10.8	9.4	15.8
Kentucky	341	350	509	22,700	23,100	26,100	15.0	15.2	19.5
Louisiana	413	408	519	35,900	36,200	35,500	11.5	11.3	14.6
Maine	137	109	145	7,900	11,600	11,200	17.3	9.4	12.9
Maryland	1,100	1,264	1,642	93,300	93,900	104,100	11.8	13.5	15.8
Massachusetts	2,427	2,831	3,819	130,900	136,600	148,800	18.5	20.7	25.7
Michigan	3,046	3,075	4,030	116,700	122,900	131,800	26.1	25.0	30.6
Minnesota	1,943	2,059	2,902	69,400	76,800	81,600	28.0	26.8	35.6
Mississippi	138	182	225	15,700	14,100	16,100	8.8	12.9	14.0
Missouri	819	870	1,087	53,100	59,700	61,000	15.4	14.6	17.8
Montana	141	105	142	8,100	10,200	8,600	17.4	10.3	16.5
Nebraska	150	185	229	15,300	15,200	19,900	9.8	12.2	11.5
Nevada	216	226	356	11,600	10,100	10,800	18.6	22.4	33.0
New Hampshire	460	503	692	14,000	17,000	19,100	32.9	29.6	36.2
New Jersey	3,065	3,461	4,371	118,900	118,500	121,200	25.8	29.2	36.1
New Mexico	280	281	357	25,100	25,900	28,600	11.2	10.8	12.5
New York	5,266	5,421	6,903	197,400	206,900	216,000	26.7	26.2	32.0
North Carolina	1,255	1,501	1,956	75,000	84,500	93,800	16.7	17.8	20.9
North Dakota	63	50	76	4,500	4,300	4,700	14.0	11.6	16.2
Ohio	2,986	3,295	4,003	119,900	138,600	132,900	24.9	23.8	30.1
Oklahoma	545	453	545	25,500	28,600	28,100	21.4	15.8	19.4
Oregon	870	1,103	1,386	37,800	39,800	43,400	23.0	27.7	31.9
Pennsylvania	2,926	2,934	4,077	137,700	141,800	143,300	21.2	20.7	28.5
Rhode Island	263	303	341	15,600	13,500	14,200	16.9	22.4	24.0
South Carolina	521	499	654	31,800	34,200	37,500	16.4	14.6	17.4
South Dakota	44	53	78	5,400	5,400	7,000	8.1	9.8	11.1
Tennessee	708	745	1,018	50,400	47,100	44,400	14.0	15.8	22.9
Texas	4,314	4,449	6,425	229,600	232,300	254,800	18.8	19.2	25.2
Utah	554	666	748	26,100	24,400	25,200	21.2	27.3	29.7
Vermont	171	290	363	8,800	10,200	12,500	19.4	28.4	29.0
Virginia	944	917	1,151	104,500	116,200	124,100	9.0	7.9	9.3
Washington	1,257	1,510	2,038	75,800	97,900	101,500	16.6	15.4	20.1
West Virginia	151	165	166	12,000	14,100	16,500	12.6	11.7	10.1
Wisconsin	1,426	1,527	1,996	52,500	54,000	53,200	27.2	28.3	37.5
Wyoming	75	60	58	6,400	5,700	4,800	11.7	10.5	12.1
Puerto Rico	24	14	33	NA	NA	NA	NA	NA	NA

NA not available

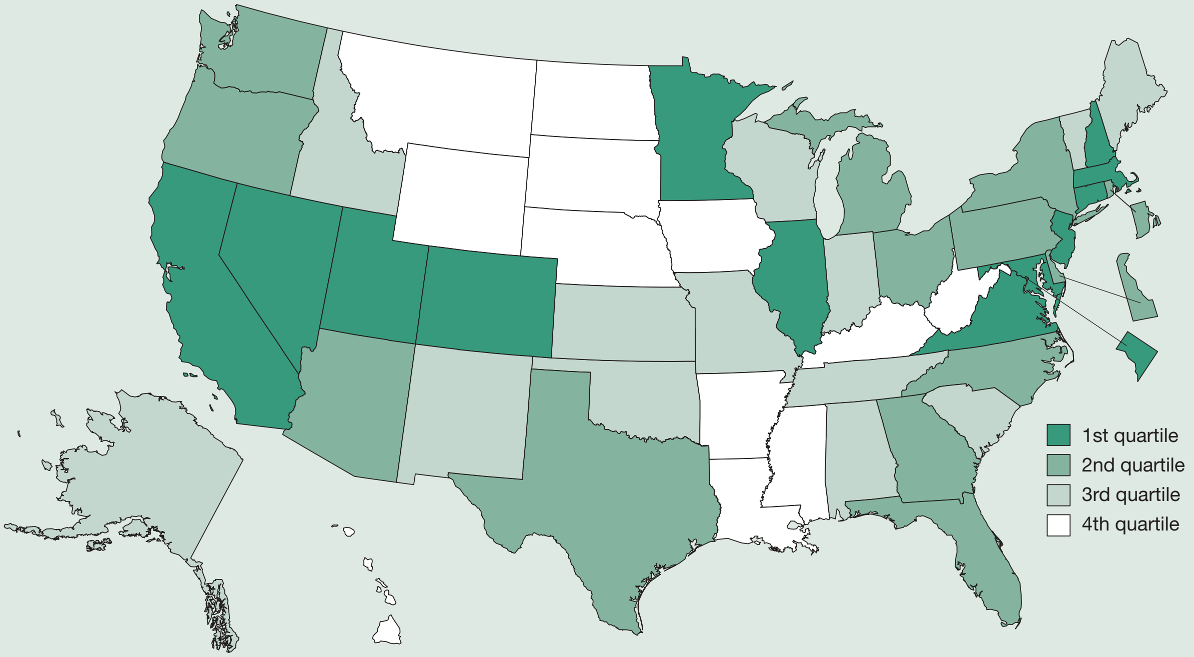
NOTES: The state total for each year is the sum of the 50 states and the District of Columbia. Patents issued include utility patents and other types of U.S. documents (i.e., design patents, plant patents, reissues, defensive publications, and statutory invention registrations). The origin of a patent is determined by the residence of the first-named inventor. Individuals in S&E occupations include those who are employed in S&E at the time of survey and are included in one of the following two groups: (1) have ever received a bachelor's or higher degree in an S&E field or (2) have a non-S&E bachelor's or higher degree and were in an S&E occupation at the time of the 1993 Scientists and Engineers Statistical Data System (SESTAT) surveys. S&E occupations include mathematical, computer, life, physical, and social scientists; engineers; and postsecondary teachers in any S&E degree field. Because SESTAT survey sample designs do not include geography, the reliability of estimates in some states may be poor because of small sample size.

SOURCES: U.S. Patent and Trademark Office, Information Products Division/Technology Assessment and Forecast Branch, *Patent Counts by Country/State and Year, All Patents, All Types, January 1, 1977–December 31, 2001,* 2002; and National Science Foundation, Division of Science Resources Statistics, SESTAT.

Science & Engineering Indicators – 2004

High-Technology Share of All Business Establishments

Figure 8-22
Quartile groups for high-technology share of all business establishments: 2000



1st quartile (10.53–6.71 percent)	2nd quartile (6.54–5.31 percent)	3rd quartile (5.21–4.22 percent)	4th quartile (4.21–2.98 percent)
California	Arizona	Alabama	Arkansas
Colorado	Delaware	Alaska	Hawaii
Connecticut	Florida	Idaho	Iowa
District of Columbia	Georgia	Indiana	Kentucky
Illinois	Michigan	Kansas	Louisiana
Maryland	New York	Maine	Mississippi
Massachusetts	North Carolina	Missouri	Montana
Minnesota	Ohio	New Mexico	Nebraska
Nevada	Oregon	Oklahoma	North Dakota
New Hampshire	Pennsylvania	South Carolina	South Dakota
New Jersey	Rhode Island	Tennessee	West Virginia
Utah	Texas	Vermont	Wyoming
Virginia	Washington	Wisconsin	

SOURCES: U.S. Bureau of the Census, Standard Statistical Establishment List, special tabulations; and U.S. Bureau of the Census, *County Business Patterns.* See table 8-22.

This indicator measures the portion of business establishments that are classified as high-technology industries. High-technology industries are identified as those having at least twice the employment proportion of the all-industries average, both in research and development and in all technology occupations.

State economies with a high percentage of their business establishments in high-technology industries are likely to be well positioned to take advantage of new technological advances. Because of a recent change in the industrial classification system, this indicator covers only 1998–2000.

Findings

- The number of high-technology establishments rose from 402,000 in 1998 to 428,000 in 2000.
- The percentage of establishments classified as high technology grew from 5.8 to 6.1 percent of total business establishments in the period 1998–2000.
- The state distribution of this indicator is similar to that of three other indicators: bachelor's degree holders, S&E doctoral degree holders in the workforce, and workforce in S&E occupations.

Table 8-22

High-technology share of all business establishments, by state: 1998, 1999, and 2000

	High-technology establishments			All business establishments			High-technology/business establishments (percent)		
State	1998	1999	2000	1998	1999	2000	1998	1999	2000
All states	402,096	415,466	428,061	6,941,822	7,008,444	7,070,048	5.79	5.93	6.05
Alabama	4,068	4,162	4,208	100,316	100,507	99,817	4.06	4.14	4.22
Alaska	730	762	783	18,212	18,433	18,501	4.01	4.13	4.23
Arizona	6,877	7,155	7,493	110,245	112,545	114,804	6.24	6.36	6.53
Arkansas	2,003	2,090	2,170	62,353	62,737	63,185	3.21	3.33	3.43
California	54,998	57,602	60,799	773,925	784,935	799,863	7.11	7.34	7.60
Colorado	10,472	10,865	11,361	130,354	133,743	137,528	8.03	8.12	8.26
Connecticut	6,376	6,357	6,356	92,362	92,454	92,436	6.90	6.88	6.88
Delaware	1,327	1,392	1,426	22,871	23,381	23,771	5.80	5.95	6.00
District of Columbia	1,906	2,005	2,069	19,571	19,469	19,655	9.74	10.30	10.53
Florida	23,982	25,037	25,873	420,638	424,089	428,438	5.70	5.90	6.04
Georgia	12,234	12,706	13,110	194,213	197,759	200,442	6.30	6.42	6.54
Hawaii	1,162	1,225	1,256	29,603	29,569	29,853	3.93	4.14	4.21
Idaho	1,435	1,551	1,632	35,961	36,975	37,429	3.99	4.19	4.36
Illinois	20,643	21,292	21,479	304,533	306,899	308,067	6.78	6.94	6.97
Indiana	6,790	6,970	7,049	146,197	146,528	146,321	4.64	4.76	4.82
Iowa	2,604	2,672	2,677	80,838	81,213	80,890	3.22	3.29	3.31
Kansas	3,309	3,466	3,611	74,019	74,486	74,939	4.47	4.65	4.82
Kentucky	3,381	3,495	3,491	89,593	89,946	89,921	3.77	3.89	3.88
Louisiana	4,132	4,150	4,223	100,667	101,020	101,016	4.10	4.11	4.18
Maine	1,585	1,667	1,708	38,334	38,878	39,466	4.13	4.29	4.33
Maryland	9,337	9,713	10,030	126,577	127,431	128,467	7.38	7.62	7.81
Massachusetts	13,949	14,281	14,598	167,929	173,267	176,222	8.31	8.24	8.28
Michigan	12,839	13,081	13,255	235,403	236,456	236,912	5.45	5.53	5.59
Minnesota	9,384	9,714	10,014	134,981	137,305	139,080	6.95	7.07	7.20
Mississippi	1,832	1,835	1,866	59,771	59,834	59,788	3.07	3.07	3.12
Missouri	6,355	6,558	6,667	143,912	144,874	144,755	4.42	4.53	4.61
Montana	1,206	1,263	1,321	30,957	31,365	31,849	3.90	4.03	4.15
Nebraska	1,834	1,858	1,955	48,655	48,968	49,623	3.77	3.79	3.94
Nevada	2,814	3,021	3,233	44,613	46,890	48,178	6.31	6.44	6.71
New Hampshire	2,840	2,846	2,874	36,842	37,180	37,414	7.71	7.65	7.68
New Jersey	18,964	19,550	20,089	230,860	231,823	233,559	8.21	8.43	8.60
New Mexico	2,143	2,192	2,227	42,608	42,918	42,782	5.03	5.11	5.21
New York	25,289	26,291	27,507	481,962	485,954	492,073	5.25	5.41	5.59
North Carolina	10,078	10,468	10,887	198,690	201,706	203,903	5.07	5.19	5.34
North Dakota	570	592	606	20,288	20,380	20,139	2.81	2.90	3.01
Ohio	14,234	14,481	14,566	270,343	270,766	270,509	5.27	5.35	5.38
Oklahoma	3,752	3,774	3,810	84,881	84,854	85,094	4.42	4.45	4.48
Oregon	5,468	5,576	5,693	99,183	99,945	100,645	5.51	5.58	5.66
Pennsylvania	15,320	15,725	16,090	292,659	293,491	294,741	5.23	5.36	5.46
Rhode Island	1,444	1,464	1,516	28,245	28,240	28,534	5.11	5.18	5.31
South Carolina	3,942	4,102	4,119	94,985	96,440	97,146	4.15	4.25	4.24
South Dakota	684	694	723	23,521	23,693	23,783	2.91	2.93	3.04
Tennessee	5,421	5,520	5,561	131,110	131,116	130,876	4.13	4.21	4.25
Texas	27,094	27,734	28,410	462,875	467,087	471,509	5.85	5.94	6.03
Utah	3,399	3,529	3,750	52,025	53,809	55,379	6.53	6.56	6.77
Vermont	1,068	1,079	1,109	21,261	21,598	21,564	5.02	5.00	5.14
Virginia	12,767	13,423	14,015	172,182	173,550	175,582	7.41	7.73	7.98
Washington	9,627	9,913	10,175	161,473	162,932	164,018	5.96	6.08	6.20
West Virginia	1,208	1,243	1,224	41,703	41,451	41,047	2.90	3.00	2.98
Wisconsin	6,497	6,598	6,655	138,635	139,646	140,415	4.69	4.72	4.74
Wyoming	723	727	742	17,888	17,909	18,120	4.04	4.06	4.09
Puerto Rico	NA	NA	NA	42,577	43,464	44,015	NA	NA	NA

NA not available

NOTE: The state total for each year is the sum of the 50 states and the District of Columbia.

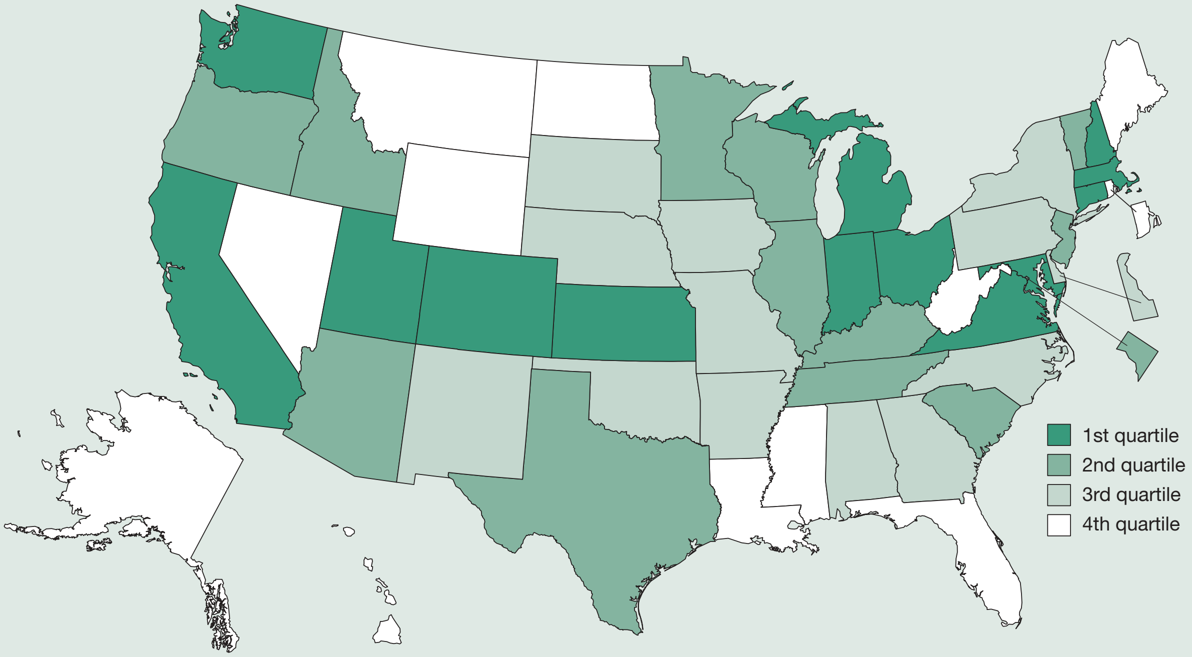
SOURCES: U.S. Bureau of the Census, Standard Statistical Establishment List, special tabulations; and U.S. Bureau of the Census, *County Business Patterns,* various years.

Science & Engineering Indicators – 2004

Employment in High-Technology Establishments as Share of Total Employment

Figure 8-23

Quartile groups for employment in high-technology establishments as share of total employment: 2000



1st quartile (12.62–9.68 percent)	2nd quartile (9.62–7.99 percent)	3rd quartile (7.98–6.52 percent)	4th quartile (6.24–2.38 percent)
California	Arizona	Alabama	Alaska
Colorado	District of Columbia	Arkansas	Florida
Connecticut	Idaho	Delaware	Hawaii
Indiana	Illinois	Georgia	Louisiana
Kansas	Kentucky	Iowa	Maine
Maryland	Minnesota	Missouri	Mississippi
Massachusetts	New Jersey	Nebraska	Montana
Michigan	Oregon	New Mexico	Nevada
New Hampshire	South Carolina	New York	North Dakota
Ohio	Tennessee	North Carolina	Rhode Island
Utah	Texas	Oklahoma	West Virginia
Virginia	Vermont	Pennsylvania	Wyoming
Washington	Wisconsin	South Dakota	

SOURCES: U.S. Bureau of the Census, Standard Statistical Establishment List, special tabulations; and U.S. Bureau of the Census, *County Business Patterns.* See table 8-23.

This indicator measures the extent to which the workforce in a state is employed in high-technology industries. High-technology industries are identified as those with at least twice the share of employment of the all-industries average, in both research and development in all technology occupations.

State economies with a high value for this indicator are probably well positioned to take advantage of new technological advances because they have a relatively larger pool of experienced high-technology workers. Because of a recent shift in the industrial classification system, this indicator covers only 1998–2000.

Findings

- High-technology employment grew from 9.6 to 10.1 million workers over the 1998–2000 period, but total employment grew marginally faster.
- High-technology employment for the period ranged from about 8.8 to 8.9 percent of the total workforce.
- Not surprisingly, states were distributed similarly on the high-technology employment and high-technology establishment indicators.
- On the high-technology employment indicator, states varied greatly in 2000, ranging from 2.4 to 12.6 percent.

Table 8-23
Employment in high-technology establishments as share of total employment, by state: 1998, 1999, and 2000

	Employment in high-technology establishment			All employment			High-technology/ all employment (percent)		
State	1998	1999	2000	1998	1999	2000	1998	1999	2000
All states	9,649,938	9,836,581	10,086,689	108,117,731	110,705,661	114,064,976	8.93	8.89	8.84
Alabama	113,340	117,681	119,207	1,604,110	1,633,909	1,653,074	7.07	7.20	7.21
Alaska	6,518	6,660	7,772	196,135	198,459	204,887	3.32	3.36	3.79
Arizona	157,010	152,917	166,678	1,763,508	1,838,277	1,919,353	8.90	8.32	8.68
Arkansas	62,620	62,576	64,564	944,935	954,948	990,830	6.63	6.55	6.52
California	1,312,754	1,335,536	1,397,776	12,026,989	12,356,363	12,884,692	10.92	10.81	10.85
Colorado	166,494	176,315	190,282	1,757,628	1,821,717	1,913,302	9.47	9.68	9.95
Connecticut	160,575	163,679	166,788	1,493,964	1,530,539	1,546,250	10.75	10.69	10.79
Delaware	29,932	30,138	29,208	354,643	360,735	377,277	8.44	8.35	7.74
District of Columbia	32,038	34,325	36,111	402,070	404,372	414,983	7.97	8.49	8.70
Florida	316,257	328,324	339,093	5,756,353	5,954,982	6,217,386	5.49	5.51	5.45
Georgia	228,511	244,728	256,208	3,198,950	3,363,797	3,483,500	7.14	7.28	7.35
Hawaii	8,258	9,475	10,292	416,571	419,047	432,092	1.98	2.26	2.38
Idaho	41,044	40,176	43,356	423,615	434,461	450,788	9.69	9.25	9.62
Illinois	476,305	485,905	491,433	5,221,782	5,342,675	5,501,036	9.12	9.09	8.93
Indiana	291,151	293,800	302,599	2,540,866	2,580,408	2,650,774	11.46	11.39	11.42
Iowa	100,990	102,359	101,015	1,213,285	1,239,354	1,265,064	8.32	8.26	7.98
Kansas	117,366	117,303	116,476	1,081,941	1,111,884	1,128,732	10.85	10.55	10.32
Kentucky	116,730	120,628	126,237	1,443,015	1,469,315	1,513,722	8.09	8.21	8.34
Louisiana	94,915	90,385	89,305	1,577,220	1,579,949	1,592,357	6.02	5.72	5.61
Maine	22,534	24,051	26,310	456,715	475,149	491,780	4.93	5.06	5.35
Maryland	192,782	199,997	203,618	1,938,727	1,988,950	2,058,304	9.94	10.06	9.89
Massachusetts	357,070	371,152	388,928	2,924,913	2,971,052	3,087,044	12.21	12.49	12.60
Michigan	507,762	513,378	514,017	3,919,567	3,996,300	4,072,786	12.95	12.85	12.62
Minnesota	201,359	207,282	210,453	2,271,671	2,338,642	2,395,361	8.86	8.86	8.79
Mississippi	60,182	56,924	56,283	937,023	948,883	956,781	6.42	6.00	5.88
Missouri	201,038	195,800	178,522	2,310,122	2,350,965	2,398,979	8.70	8.33	7.44
Montana	10,312	11,108	12,256	277,144	288,358	296,220	3.72	3.85	4.14
Nebraska	57,718	57,370	59,228	720,252	733,905	751,076	8.01	7.82	7.89
Nevada	26,300	28,180	31,814	800,861	854,358	902,775	3.28	3.30	3.52
New Hampshire	58,282	56,455	53,475	518,526	528,902	546,400	11.24	10.67	9.79
New Jersey	299,146	314,335	322,935	3,368,365	3,440,721	3,548,429	8.88	9.14	9.10
New Mexico	43,681	43,489	43,137	540,186	541,386	549,352	8.09	8.03	7.85
New York	486,679	497,419	513,472	6,993,814	7,135,960	7,353,209	6.96	6.97	6.98
North Carolina	260,203	265,907	268,284	3,223,178	3,324,155	3,385,492	8.07	8.00	7.92
North Dakota	15,542	16,562	15,916	249,476	250,292	255,178	6.23	6.62	6.24
Ohio	479,462	478,007	484,110	4,806,046	4,867,368	5,001,980	9.98	9.82	9.68
Oklahoma	86,402	84,772	85,533	1,167,709	1,171,356	1,201,606	7.40	7.24	7.12
Oregon	108,322	111,244	108,254	1,310,750	1,332,403	1,355,442	8.26	8.35	7.99
Pennsylvania	375,364	387,493	394,786	4,906,190	4,986,591	5,087,237	7.65	7.77	7.76
Rhode Island	23,134	23,782	24,809	402,485	405,445	415,168	5.75	5.87	5.98
South Carolina	140,065	137,783	137,014	1,526,106	1,561,727	1,601,532	9.18	8.82	8.56
South Dakota	24,438	24,217	23,346	289,422	295,139	306,704	8.44	8.21	7.61
Tennessee	189,396	192,935	195,796	2,299,348	2,338,780	2,390,322	8.24	8.25	8.19
Texas	685,349	684,424	703,206	7,570,820	7,763,815	8,026,438	9.05	8.82	8.76
Utah	84,581	86,233	89,486	866,146	889,355	917,089	9.77	9.70	9.76
Vermont	20,766	21,262	22,761	239,034	246,320	253,541	8.69	8.63	8.98
Virginia	308,922	326,351	348,426	2,700,589	2,791,977	2,903,548	11.44	11.69	12.00
Washington	241,200	248,509	258,234	2,134,598	2,209,129	2,267,485	11.30	11.25	11.39
West Virginia	31,065	31,039	30,903	547,234	545,495	558,171	5.68	5.69	5.54
Wisconsin	211,695	219,624	220,093	2,319,343	2,368,404	2,414,834	9.13	9.27	9.11
Wyoming	6,379	6,587	6,884	163,791	169,188	174,614	3.89	3.89	3.94
Puerto Rico	NA	NA	NA	687,707	720,226	727,449	NA	NA	NA

NA not available

NOTE: The state total for each year is the sum of the 50 states and the District of Columbia.

SOURCES: U.S. Bureau of the Census, Standard Statistical Establishment List, special tabulations; and U.S. Bureau of the Census, *County Business Patterns,* various years.

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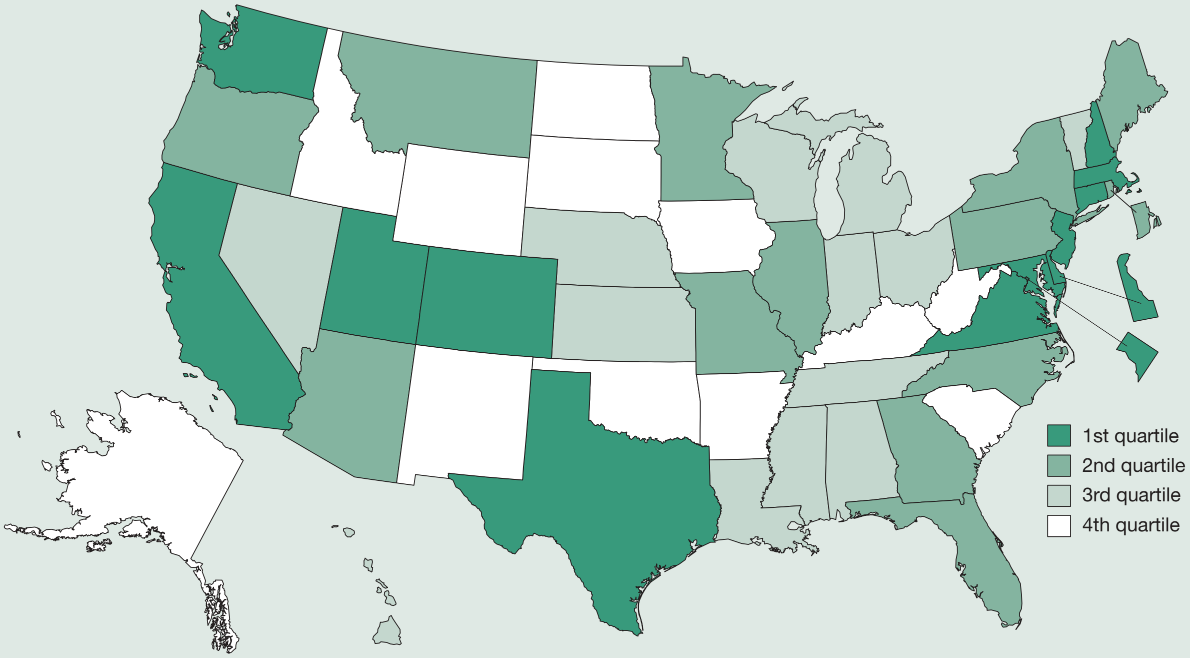
Venture Capital Disbursed per $1,000 of Gross State Product

Figure 8-24

Quartile groups for venture capital disbursed per $1,000 GSP: 2001



1st quartile ($17.07–$3.13)	2nd quartile ($3.05–$0.95)	3rd quartile ($0.87–$0.28)	4th quartile ($0.26–0.00)
California	Arizona	Alabama	Alaska
Colorado	Florida	Hawaii	Arkansas
Connecticut	Georgia	Indiana	Idaho
Delaware	Illinois	Kansas	Iowa
District of Columbia	Maine	Louisiana	Kentucky
Maryland	Minnesota	Michigan	New Mexico
Massachusetts	Missouri	Mississippi	North Dakota
New Hampshire	Montana	Nebraska	Oklahoma
New Jersey	New York	Nevada	South Carolina
Texas	North Carolina	Ohio	South Dakota
Utah	Oregon	Tennessee	West Virginia
Virginia	Pennsylvania	Vermont	Wyoming
Washington	Rhode Island	Wisconsin	

SOURCES: PricewaterhouseCoopers, Thomson Venture Economics, and National Venture Capital Association MoneyTree Survey; U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data; and Government of Puerto Rico. See table 8-24.

Venture capital represents an important source of funding for start-up companies. This indicator was designed to show the relative magnitude of venture capital investments in a state after adjusting for the size of the state's economy. The indicator is expressed as dollars of venture capital disbursed per $1,000 gross state product (GSP).

Data for this indicator were calculated for 1995, 1998, and 2001. Although venture capital data are available for 2002, GSP values have not been released.

Findings

- The amount of venture capital invested in the United States increased more than 10-fold, from nearly $8 billion in 1995 to a record $106 billion in 2000, before falling to $41 billion in 2001. (By 2002, it declined to $21 billion.)
- In 2001, the state average for venture capital disbursed per $1,000 GSP was $4.06, up from $1.05 in 1995.
- At the state level in 2001, this value ranged from a high of $17.07 per $1,000 GSP to no venture capital investment.
- The state distribution of venture capital was similar to that for the high-technology indicators.

Table 8-24

Venture capital disbursed per $1,000 of GSP, by state: 1995, 1998, and 2001

	Venture capital disbursed (thousands of dollars)			GSP (millions of dollars)			Venture capital/$1,000 GSP		
State	1995	1998	2001	1995	1998	2001	1995	1998	2001
All states	7,674,878	21,485,964	41,174,693	7,309,513	8,750,175	10,137,194	1.05	2.46	4.06
Alabama	36,501	87,240	86,697	95,514	109,672	121,490	0.38	0.80	0.71
Alaska	0	0	0	24,791	24,651	28,581	0.00	0.00	0.00
Arizona	93,416	210,540	267,150	104,586	132,897	160,687	0.89	1.58	1.66
Arkansas	5,012	6,900	10,400	53,809	61,298	67,913	0.09	0.11	0.15
California	2,803,765	8,352,209	16,613,254	925,931	1,125,331	1,359,265	3.03	7.42	12.22
Colorado	331,734	964,907	1,386,050	109,021	139,860	173,772	3.04	6.90	7.98
Connecticut	126,470	447,977	576,553	118,645	142,701	166,165	1.07	3.14	3.47
Delaware	4,432	0	166,130	27,575	32,693	40,509	0.16	0.00	4.10
District of Columbia	185	81,200	201,857	48,408	52,145	64,459	0.00	1.56	3.13
Florida	242,326	432,354	961,096	344,771	415,564	491,488	0.70	1.04	1.96
Georgia	162,982	389,938	915,043	203,505	254,891	299,874	0.80	1.53	3.05
Hawaii	0	4,165	37,811	37,243	39,371	43,710	0.00	0.11	0.87
Idaho	15,200	30,285	6,272	27,155	31,041	36,905	0.56	0.98	0.17
Illinois	225,333	337,617	897,765	359,451	423,175	475,541	0.63	0.80	1.89
Indiana	9,163	26,955	53,838	148,447	176,110	189,919	0.06	0.15	0.28
Iowa	14,188	10,275	6,041	71,687	83,069	90,942	0.20	0.12	0.07
Kansas	6,600	12,563	41,023	64,069	76,648	87,196	0.10	0.16	0.47
Kentucky	16,979	37,460	28,505	91,472	107,648	120,266	0.19	0.35	0.24
Louisiana	30,450	69,163	75,872	112,157	122,580	148,697	0.27	0.56	0.51
Maine	1,500	61,828	35,501	27,987	32,208	37,449	0.05	1.92	0.95
Maryland	118,439	324,796	953,919	139,495	164,100	195,007	0.85	1.98	4.89
Massachusetts	693,963	2,025,756	4,911,779	197,469	241,369	287,802	3.51	8.39	17.07
Michigan	73,517	115,982	103,580	254,179	293,173	320,470	0.29	0.40	0.32
Minnesota	163,846	375,671	542,583	131,841	163,009	188,050	1.24	2.30	2.89
Mississippi	2,749	3,500	40,000	54,562	61,709	67,125	0.05	0.06	0.60
Missouri	80,382	683,810	370,170	139,547	163,425	181,493	0.58	4.18	2.04
Montana	0	500	24,820	17,537	19,971	22,635	0.00	0.03	1.10
Nebraska	16,102	33,035	16,963	44,084	51,349	56,967	0.37	0.64	0.30
Nevada	575	24,741	30,450	49,377	63,786	79,220	0.01	0.39	0.38
New Hampshire	30,690	179,239	256,706	32,388	40,529	47,183	0.95	4.42	5.44
New Jersey	284,600	498,412	1,483,098	271,435	316,875	365,388	1.05	1.57	4.06
New Mexico	3,550	7,700	9,400	42,170	48,488	55,426	0.08	0.16	0.17
New York	302,597	1,311,411	2,183,533	597,593	718,686	826,488	0.51	1.82	2.64
North Carolina	219,485	362,780	634,547	194,634	241,220	275,615	1.13	1.50	2.30
North Dakota	9,835	500	1,517	14,529	17,053	19,005	0.68	0.03	0.08
Ohio	68,670	274,597	236,753	295,668	346,648	373,708	0.23	0.79	0.63
Oklahoma	6,100	6,950	24,800	69,960	82,189	93,855	0.09	0.08	0.26
Oregon	41,711	53,497	223,885	81,092	102,943	120,055	0.51	0.52	1.86
Pennsylvania	141,038	619,638	904,734	318,765	365,038	408,373	0.44	1.70	2.22
Rhode Island	6,020	7,900	62,089	25,703	30,838	36,939	0.23	0.26	1.68
South Carolina	53,385	53,923	25,980	86,880	101,384	115,204	0.61	0.53	0.23
South Dakota	0	0	500	18,257	20,570	24,251	0.00	0.00	0.02
Tennessee	175,201	124,234	107,041	136,821	162,228	182,515	1.28	0.77	0.59
Texas	431,854	1,078,695	3,309,362	513,882	641,405	763,874	0.84	1.68	4.33
Utah	11,200	116,490	222,959	46,290	59,084	70,409	0.24	1.97	3.17
Vermont	3,208	1,414	11,600	13,974	16,294	19,149	0.23	0.09	0.61
Virginia	271,620	807,401	966,573	188,963	228,049	273,070	1.44	3.54	3.54
Washington	329,414	755,106	1,049,591	151,265	192,031	222,950	2.18	3.93	4.71
West Virginia	0	0	1,650	36,315	39,024	42,368	0.00	0.00	0.04
Wisconsin	8,891	74,713	93,756	133,694	157,735	177,354	0.07	0.47	0.53
Wyoming	0	0	3,500	14,920	16,420	20,418	0.00	0.00	0.17
Puerto Rico	7,760	1,300	27,000	28,452	35,161	NA	0.27	0.04	NA

GSP gross state product

NA not available

NOTES: The state total for each year is the sum of the 50 states and the District of Columbia. GSP is reported in current dollars.

SOURCES: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey, special tabulations; U.S. Department of Commerce, Bureau of Economic Analysis, Gross State Product data; and Government of Puerto Rico, Office of the Governor.

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Technical Note: Defining High-Technology Industries

The Bureau of Labor Statistics (BLS) developed a list of high-technology industries based on Standard Industrial Classification (SIC) codes in 1999.[1] The list was based on measures of industry employment in both R&D and technology-oriented occupations, using Occupational Employment Statistics surveys from 1993 to 1995 in which employers were asked to explicitly report the number of workers engaged in R&D activity. The researchers identified 31 three-digit SIC R&D-intensive industries in which the number of R&D workers and technology-oriented occupations accounted for a proportion of employment that was at least twice the average for all industries surveyed. These industries had at least 6 R&D and 76 technology-oriented workers per 1,000 workers. The BLS list comprised 27 manufacturing and 4 service industries.

The Office of Technology Policy, with assistance from the Bureau of the Census, converted the BLS list of SIC codes into the newer North American Industrial Classification System (NAICS) codes using the concordance between the two classification systems. The process necessitated both splitting and combining codes. The resulting list of high-technology NAICS codes comprises 39 categories that range from four- to six-digit detail. Twenty-nine categories identify manufacturing industries, and 10 identify service industries. The industry categories included in the high-technology segment are shown in table 8-25.

Table 8-25
High-technology NAICS codes

NAICS code	Industry
32411	Petroleum refineries
3251	Basic chemical manufacturing
3252	Resin, synthetic rubber, and artificial and synthetic fibers and filaments manufacturing
3253	Pesticide, fertilizer, and other agricultural chemical manufacturing
3254	Pharmaceutical and medicine manufacturing
3255	Paint, coating, and adhesive manufacturing
3256	Soap, cleaning compound, and toilet preparation manufacturing
3259	Other chemical product and preparation manufacturing
332992	Ordnance and accessories manufacturing—small arms ammunition manufacturing
332993	Ordnance and accessories manufacturing—ammunition (except small arms) manufacturing
332994	Ordnance and accessories manufacturing—small arms manufacturing
332995	Ordnance and accessories manufacturing—other ordnance and accessories manufacturing
3331	Agriculture, construction, and mining machinery manufacturing
3332	Industrial machinery manufacturing
3333	Commercial and service industry machinery manufacturing
3336	Engine, turbine, and power transmission equipment manufacturing
3339	Other general purpose machinery manufacturing
3341	Computer and peripheral equipment manufacturing
3342	Communications equipment manufacturing
3343	Audio and video equipment manufacturing
3344	Semiconductor and other electronic component manufacturing
3345	Navigational, measuring, electromedical, and control instruments manufacturing
3346	Manufacturing and reproducing magnetic and optical media
3353	Electrical equipment manufacturing
33599	All other electrical equipment and component manufacturing
3361	Motor vehicle manufacturing
3362	Motor vehicle body and trailer manufacturing
3363	Motor vehicle parts manufacturing
3364	Aerospace product and parts manufacturing
3391	Medical equipment and supplies manufacturing
5112	Software publishers
514191	On-line information services
5142	Data processing services
5413	Architectural, engineering, and related services
5415	Computer systems design and related services
5416	Management, scientific, and technical consulting services
5417	Scientific research and development services
6117	Educational support services
811212	Computer and office machine repair and maintenance

NAICS North American Industrial Classification System

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[1] Hecker, D. 1999. High-technology employment: A broader view. *Monthly Labor Review* 122(6):18.

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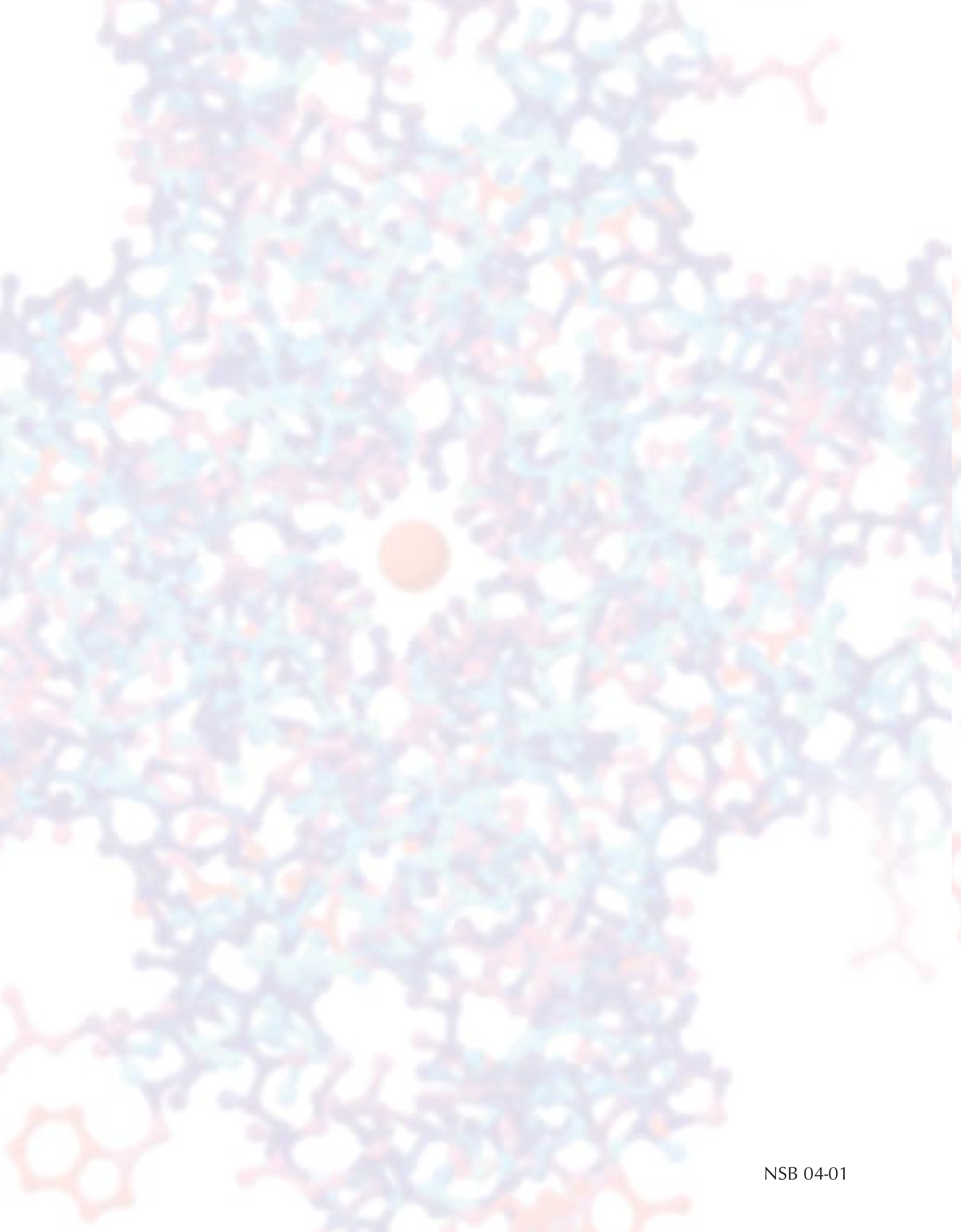

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